

Implant Laboratory Procedures: A Step-by-Step Guide

*Carl Drago
Thomas Peterson*

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Implant Laboratory Procedures: A Step-by-Step Guide

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Carl Drago, DDS, MS

Biomet 3i

Palm Beach Gardens, Florida

Nova SE University College of Dental Medicine

Fort Lauderdale, Florida

Thomas Peterson, CDT, MDT

North Shore Dental Laboratories

Lynn, Massachusetts



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Dedication

Dr. Carl Drago dedicates this book to his family, the very fabric of his life: past, present, and future.



Image by Stephanie Drago Bottner

Contents

Foreword	xiii
Preface	xv
Acknowledgments	xvii
Notice for Readers	xix
Registered Trademarks	xxi
Chapter 1: Introduction to Implant Dentistry	3
Introduction	3
Loading Protocols	3
<i>Traditional, Two-Stage, Unloaded Healing</i>	3
<i>Single-Stage, Unloaded Healing</i>	3
<i>Immediate Occlusal Loading</i>	3
<i>Immediate Nonocclusal Loading</i>	3
Abutments	4
Abutment Selection	6
Surgical Guides	7
<i>Conventional</i>	7
<i>Computer Generated</i>	9
Chapter 2: Mandibular Two-Implant Overdenture	11
Introduction	11
Clinical Patient Presentation	12
Diagnosis	12
Assessment	12
Diagnostic Casts	14
Custom Impression Trays	15
Definitive Intraoral Impression	16
Master Cast	16
Record Bases	17
Articulator Mounting	18
Wax Dentures	18
Processing	21
Insertion	24
Chapter 3: Immediate Occlusal Loading—Maxillary Hybrid Prosthesis with Cast Metal Framework (The Columbus Bridge Protocol)	27
Introduction	27
Clinical Patient Presentation	28
Diagnoses	30
Assessment	30
Diagnostics	31
Articulator Mounting	33
Surgical Guide	33
Surgery/Implant Placement	40
Abutment Placement	42
Abutment Impression	44

Jaw Relation Records	46
Master Cast	47
Articulator Mounting	48
Fabrication of Interim Screw-Retained Implant Prosthesis	49
<i>Construction of the Cast Metal Framework</i>	49
<i>Construction of the Hybrid Prosthesis</i>	51
Insertion	54
One-Week Post-Insertion Clinical Visit	56

Chapter 4: Robot Analog Placement and CAD/CAM Abutments 61

Introduction	61
The Encode Complete Restorative System	64
Clinical Patient Presentation	67
Diagnosis	67
Assessment	72
Diagnostic Casts/Surgical Guide	72
Implant Surgery	73
Placement of Healing Abutment	73
Placement of Encode Healing Abutment and Encode Healing Abutment Impression	74
Master Cast	76
Articulator Mounting	77
Encode Complete Work Order	77
Scanning	79
Abutment Design/Milling	80
Robotic Placement of Lab Analog into Cast (Robocast)	81
Fabrication of Porcelain-Fused-to-Metal Crown	85
Clinical Insertion	86

Chapter 5: Maxillary Implant-Retained Primary Bar (CAM StructSURE Precision Milled Copy Milled Bar Framework) with Secondary Casting Maxillary Overdenture; Mandibular CAM StructSURE Precision Milled Bar for Mandibular Hybrid Screw-Retained Prosthesis 93

Introduction	93
Clinical Patient Presentation	93
Diagnoses	95
Assessment	95
Diagnostic Casts/Surgical Guide	96
Implant Surgery	96
Implant-Level Impression—Laboratory Procedures	98
Master Cast	98
Record Bases/Jaw Relation Records	100
Articulator Mounting/Wax Dentures/Verification Index	102
Overview of the Design/Construction of CAD/CAM Frameworks	104
<i>Maxillary Copy Milled Bar</i>	105
<i>Electroformed Bar Sleeves</i>	108
<i>Tertiary Casting</i>	109
<i>Mandibular CAM StructSURE Precision Milled Bar</i>	111
<i>Silicoating</i>	113
Denture Setup on CAD/CAM Frameworks	114
Clinical Try-In Appointment	114
Processing	116
Insertion	121

Chapter 6: Computed Tomography (CT)-Guided Surgery/Immediate Occlusal Loading with a Full-Arch Prosthesis in the Edentulous Mandible	127
Immediate Occlusal Loading	127
Tilted Implants	127
Diagnostic Imaging	127
Computed Tomography (CT)	130
Interactive CT (ICT)	131
Interactive Computer Software	132
Surgical Guides	132
Master Tubes	133
Prosthetic Laboratory Kit—Implant Analog Mounts	133
Surgical Kit Components	134
Fabrication of a Master Cast for an Immediate, Fixed Provisional Prosthesis	135
Abutment Selection for Fixed, Screw-Retained Provisional Prostheses	136
Fabrication of a Screw-Retained Provisional Prosthesis	137
Clinical Patient Presentation	139
Radiographs	141
Diagnosis	141
Assessment	142
Treatment Plan	142
Construction of Wax Dentures	142
Clinical Try-In of the Wax Dentures	145
Fabrication of CT Scanning Appliance	146
Intraoral CT Scan	147
Fabrication of the Master Cast with Implant Analogs	150
Laboratory Abutment Selection and Placement	153
Framework Fabrication (Provisional Prosthesis)	154
Provisional Prosthesis	155
Surgical Implant Placement	157
Clinical Abutment Placement	158
Insertion of Provisional Prosthesis	161
Postoperative Visit	162
Chapter 7: Three-Unit Implant-Retained Porcelain-Fused-to-Metal Fixed Partial Denture with Premachined, Fixed Collar Height Titanium Abutments	165
Introduction	165
Clinical Patient Presentation	168
Diagnosis	168
Assessment	168
Abutment Selection	169
Diagnostics	169
Surgery	169
Abutment Impression	172
Master Cast with Abutment Analogs	173
Waxing Sleeves	174
Definitive Prosthesis	175
Insertion	178
Aesthetic Evaluation	178
Chapter 8: Multiple CAD/CAM Abutments with Implant-Retained Porcelain Metal Crowns (The Encode® Complete Protocol)	181
Introduction	181
The Encode® Complete Restorative System	184

Clinical Patient Presentation	187
Diagnosis	191
Assessment	191
Diagnostic Casts/Surgical Guide	192
Implant Surgery	192
Placement of Healing Abutments	193
Placement of Encode Healing Abutments and Encode Healing Abutment Impression	194
Master Cast	196
Articulator Mounting	197
Encode Complete Work Order	198
Scanning	198
Abutment Design/Milling	200
Robotic Placement of Lab Analogs into Cast (Robocast)	201
Fabrication of Porcelain-Fused-to-Metal Crowns	202
Clinical Insertion	206

Chapter 9: Single-Unit Implant-Retained Porcelain Crown with Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) Ceramic Abutment (Encode Zirconia Abutment) 213

Introduction	213
CAD/CAM Protocol—The Encode® Complete Restorative System	219
Clinical Patient Presentation	223
Diagnosis	225
Assessment	225
Diagnostic Casts/Surgical Guide	227
Implant Surgery	228
Placement of Encode Healing Abutment	228
Master Cast	232
Articulator Mounting	232
Encode Complete Work Order	233
Scanning	235
Robotic Placement of Lab Analog into Cast (Robocast)	236
Abutment Design/Milling	240
Fabrication of Porcelain Crown	243
Clinical Insertion	247

Chapter 10: Computed Tomography (CT)-Guided Surgery/Immediate Occlusal Loading with a Full-Arch Prosthesis in Edentulous Maxillae 253

Introduction	253
Tilted Implants	254
Computed Tomography (CT)	255
CBCT	255
Interactive CT	256
Accuracy in CT Treatment Planning	256
Preoperative Planning	257
Clinical Patient Presentation	257
Radiographs	258
Diagnosis	259
Assessment	259
Treatment Plan	259
Construction of Maxillary Wax Denture	259
Clinical Try-in of the Maxillary Wax Denture	262
Fabrication of the Scanning Appliance	262

Intraoral CT Scan	264
Fabrication of the Master Cast with Implant Analogs	265
Laboratory Abutment Selection and Placement	270
Framework Fabrication (Provisional Prosthesis)	273
Provisional Prosthesis	276
Surgical Implant Placement	278
Clinical Abutment Placement	278
Insertion of Provisional Prosthesis	280
Postoperative Visit	283
 Chapter 11: Replacement of Denture Teeth and Denture Base for a Preexisting Mandibular Fixed/Detachable Prosthesis	 287
Introduction	287
Clinical Patient Presentation	289
Diagnosis	290
Assessment	291
Appointment Sequence	291
Diagnostic Casts	292
Custom Maxillary Impression Tray and Definitive Maxillary Impression	293
Maxillary Master Cast	294
Maxillary Record Base and Wax Occlusion Rim	294
Clinical Jaw Relation Records	297
First Articulator Mounting	298
Maxillary Wax Denture	298
Mandibular Master Cast	301
Second Articulator Mounting—Mandibular Master Cast	302
Mandibular Wax Denture	302
Silicoating	304
Processing	306
Insertion	308
 Index	 313

Foreword

The publication of this textbook could not have occurred at a better time. It will help dental laboratory technicians to grow in their technical skills as well as to develop their professional skills, which will benefit each dentist they encounter. Coauthored by Dr. Carl Drago and Mr. Thomas Peterson, CDT, MDT, this book is the result of their professional collaboration and unique perspective between a clinician and a dental laboratory technician, representing an oral health care partnership, ultimately providing the highest level of patient care.

Dental laboratory technology services in the United States are in a state of flux occurring at a time when there has been a diminution of recognized, accredited training programs for dental laboratory technicians. That both issues are occurring simultaneously is of great concern for any dentist who provides dental services involving indirect procedures. In essence, any form of patient care that requires fixed prosthodontics, removable prosthodontics, and/or implant prosthodontics needs a dental laboratory technician as a team player in order to provide the highest quality of care for the patient.

A book of this caliber can help enhance communication between the dentist and the dental laboratory technician. In the end, if a publication improves communication and contributes to the body of literature reinforcing sound principles, the message is simple—patients benefit from higher-quality information and improvements in oral health care.

The content is organized following patient treatment protocols, which reinforce fundamental clinical and dental laboratory concepts presented within the context of the relative sequence in delivery of patient care. The prosthodontic treatment descriptions include incorporating the latest use of technology to help achieve successful outcomes. The use of laboratory and technological advances range from the use of basic mechanical technology such as overdenture attachments to the use of advancements in computer-aided design/computer-aided manufacturing (CAD/CAM) abutments, milling processes, and adjunctive procedures such as computed tomography-guided surgery. These advancements are presented in an instructional manner, making it possible for those reading the information to improve overall care.

To paraphrase a radio talk show host, a computer has more information and knowledge than any one professor but has no wisdom. This book provides information based on translation of research and development into years of clinical dental practice experience so we can benefit from Dr. Drago's and Mr. Peterson's wisdom.

Lily T. Garcia, DDS, MS
Professor and Chair
Department of Prosthodontics
University of Texas Health Science Center
at San Antonio Dental School

Preface

This textbook was written in response to numerous requests of the authors, by participants in their combined seminars, to provide laboratory guidelines to clinicians and dental laboratory technicians for both complex and routine implant restorations. Dental laboratory technicians wanted to understand some of the challenges that clinicians face in developing treatment plans and then performing the treatments for patients. Laboratory technicians also expressed interest in viewing photographs of clinical treatments and understanding some of the challenges

clinicians encounter during implant treatment. Clinicians wanted insights into the “behind-the-scenes” procedures used to create implant restorations. Clinicians hoped that with an increased understanding of dental laboratory implant procedures, these insights would make them better clinicians. It is our desire that we have successfully accomplished these requests.

Carl Drago, DDS, MS
Thomas Peterson, CDT, MDT

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- Chapter 2. Surgeon: Dr. C. Garry O'Connor
LaCrosse, WI
Prosthodontist: Dr. Carl Drago
LaCrosse, WI
Dental Laboratory Technician:
Andrew Gingrasso
La Crosse, WI
- Chapter 3. Clinicians: Dr. Tiziano Tealdo,
Dr. Marco Bevilacqua
Dr. Paolo Pera
Department of Prosthetic Dentistry,
University of Genoa, Genoa, Italy
Dental Laboratory Technicians:
Luca Scaglione
Piercarlo Seghesio
Santo Stefano
Belbo, Italy
- Chapter 4. Periodontist: Dr. C. Garry O'Connor
LaCrosse, WI
Dental Laboratory Technicians:
Patrick Arneaud
Tom Bruner, CDT
North Shore Dental Laboratories
Lynn, MA
Illustrator: Robin deSomer Pierce
BSMI, Palm Beach Gardens, FL
- Chapter 5. Implant Surgeon: Dr. Robert del Castillo
Miami Lakes, FL
Prosthodontist: Dr. Carl Drago
Jupiter, FL
Dental Laboratory Technicians:
Eunice Park
Robin Devine
Alan Kalivas
North Shore Dental Laboratories
Lynn, MA
Illustrator: Robin deSomer Pierce
BSMI, Palm Beach Gardens, FL
- Chapter 6. Implant Surgeon: Dr. Robert del Castillo
Miami Lakes, FL
Prosthodontist: Dr. Carl Drago
Jupiter, FL
Dental Laboratory Technician:
Thomas Peterson, MDT, CDT
Alexey Zorin

Chapter 7.

North Shore Dental Laboratories
Lynn, MA
Illustrator: Robin deSomer Pierce
BSMI, Palm Beach Gardens, FL
Implant Surgeon: Dr. Ronald Guttu
Gundersen Lutheran Medical Center,
LaCrosse, WI
Prosthodontist: Dr. Carl Drago
Gundersen Lutheran Medical Center,
LaCrosse, WI
Dental Laboratory Technician:
Thomas Peterson, MDT, CDT
Shawn Vittorioso
Carla Palau
North Shore Dental Laboratories,
Lynn, MA
Andrew Gingrasso
Gundersen Lutheran Medical Center,
LaCrosse, WI

Chapter 8.

Illustrator: Robin deSomer Pierce
BSMI, Palm Beach Gardens, FL
Oral Surgeon: Dr. Michael Kuzmik
Tysons Corner, VA
Prosthodontist: Dr. Benjamin Watkins III
Washington, DC
Dental Laboratory Technicians:
John Ezzell—stone work
Patrick Pak—waxing
Kevin Labarge—metal casting and
finishing
Rick Bishop—ceramist
Diplomate Dental Lab, Washington,
DC

Chapter 9.

Illustrator: Robin deSomer Pierce
BSMI, Palm Beach Gardens, FL
Prosthodontist: Dr. C Garry O'Connor
La Crosse, WI
Restorative Dentist: Dr. James Allen
West Salem, WI
PSR Designer: Nancy Cronin
Palm Beach Gardens, FL
Dental Laboratory Technicians:
Anatoliy Shakarov—milling
Alexey Zorin—waxing
Mark Power—scanning
Tom Bruner, CDT—ceramics
North Shore Dental Laboratories,
Lynn, MA
Illustrator: Robin deSomer Pierce,
BSMI, Palm Beach Gardens, FL

Chapter 10. Clinician: Dr. Robert del Castillo
Miami Lakes, FL
Dental Laboratory Technician:
Alexey Zorin
North Shore Dental Laboratories,
Lynn, MA
Illustrator: Robin deSomer Pierce
BSMI, Palm Beach Gardens, FL

Chapter 11. Prosthodontist: Dr. Carl Drago
Jupiter, FL
Dental Laboratory Technician:
Andrew Gingrasso
Onalaska, WI

Notice for Readers

The art and science of dentistry is an ever-changing field. Clinical protocols regarding dental implants have been established, changed, and modified over the past several decades. The modifications in the protocols have come about as a result of intensive clinical and laboratory research by clinicians and researchers from around the globe. No matter the clinical protocol selected by individual clinicians and dental laboratory technicians for today's procedures, reasonable and appropriate clinical precautions must be followed. As new research broadens the profession's understanding of implant dentistry, continued changes in treatments, protocols, and materials are to be expected. Readers of this textbook are advised to check with the manufacturers' instructions for use regarding new materials and implant components. It is the responsibility of the treating/attending clinicians and dental laboratory technicians, relying on their care, skill, and judgment, to determine the most optimal treatment for a given patient. Neither the publisher nor editors assume any responsibility for any injury and/or damage to persons or property as a result of the treatment protocols and procedures illustrated in this textbook.

Dr. Drago became a full-time employee of Biomet 3i in January 2007; this textbook was written after Dr. Drago was hired. This book is not an official publication of Biomet 3i, and the book, as written, reflects the combined experiences of Dr. Drago and Mr. Peterson. The book was not endorsed by Biomet 3i and should not be considered to be in any way, shape, or form as an official, Biomet 3i-sponsored text. All of the products described in the book were paid for by the clinicians involved. None of the products was donated by any of the manufacturers mentioned in the book. Dr. Drago did not receive any royalties or other forms of payment from Biomet 3i for writing this book.

For the past several years, Mr. Peterson has been a paid consultant for Biomet 3i. He has also been a consultant for other dental manufacturers. Mr. Peterson did not receive any royalties or other forms of payment from Biomet 3i for writing this book.

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Implant Laboratory Procedures:

A Step-by-Step Guide

Chapter 1: Introduction to Implant Dentistry

INTRODUCTION

Endosseous osseointegrated dental implants have added significant, predictable treatment options for patients, clinicians and dental laboratory technicians (Brånemark and others 1977; Adell and others 1981, 1990; Davarpanah and others 2002). It is now possible to predictably replace single and multiple missing teeth, as well as portions of missing hard and soft tissues, with dental implant prostheses (Figures 1.1–1.3).

LOADING PROTOCOLS

Traditional, Two-Stage, Unloaded Healing

The original dental implant treatment protocol (Brånemark) with machined-surface, titanium implants was developed for patients with edentulous mandibles, as these patients traditionally had the most difficulty adapting to complete dentures (Brånemark and others 1977; Adell and others 1981, 1990). Generally, four to five implants were placed between the mental foraminae in edentulous mandibles. The surgical procedure involved reflection of a full-thickness, mucoperiosteal flap that exposed the edentulous jaw. Osteotomies were prepared in the bone, consistent with the size of the planned implants (3.75-mm-diameter, machined-surface implants). After the implants were inserted, cover screws were placed into the implants and the flaps were closed with interrupted or continuous sutures. Patients were generally told not to wear the preexisting dentures for the following 2 weeks (Figure 1.4).

After the initial 2-week healing period, the preexisting dentures were thoroughly relieved, polished, and relined with a denture-tissue-conditioning material. The implants were allowed to heal undisturbed for the next 3–4 months. This process is sometimes identified as unloaded healing. It was presumed that loading the implants immediately after placement would inhibit osseous healing, and therefore compromise osseointegration (Adell and others 1981).

Approximately 4 months post implant placement, a second surgical procedure was performed and transmucosal abutments were placed into the implants (Figure 1.5). A screw-retained implant prosthesis was fabricated and consisted of a cast metal framework, premachined cylinders,

denture teeth, and an acrylic resin processed denture base (Figure 1.6).

Single-Stage, Unloaded Healing

In the interests of increased efficiency relative to decreasing the amount of treatment time associated with dental implants, researchers began placing implants and healing abutments at the time of implant placement. This protocol precluded a second surgical procedure. Surgeons closed the flaps around the restorative components (Figure 1.7). Sullivan and coworkers reported the results of a 5-year clinical study that demonstrated a 97+% cumulative survival rate (CSR), which was consistent with CSRs that had been reported for conventional two-stage loading protocols (Ibanez and others 2003; Sullivan and others 2005).

Immediate Occlusal Loading

Immediate occlusal loading has been defined as placing multiple implants into edentulous sites, obtaining primary stability (insertion torque values of at least 30Ncm) and rigidly splinting the implants together with implant-retained prostheses at the time of implant surgery (Testori and others 2004; Attard and Zarb 2005; Tortamano and others 2006) (Figures 1.8–1.10). There has been significant research focusing on the risk/benefit ratios of immediate loading for complete and partially edentulous patients (Schnitman and others 1990, 1997; Lazzara and others 2004). These studies have reported CSRs consistent with the CSRs reported for conventional unloaded healing protocols.

Immediate Nonocclusal Loading

The term “immediate nonocclusal loading” is used for implant restorations placed immediately after implant placement, without centric or eccentric occlusal contacts. These restorations and implants have no contact in functional occlusion (Hui and others 2001; Kan and others 2003; Drago and Lazzara 2004). Interim abutments have been designed that are easy to prepare and are relatively inexpensive to use as single-use abutments (Figure 1.11). They are generally prepared outside of a patient’s mouth and connected to the implants with conventional abutment screws (Figure 1.12). The provisional restoration was made



Figure 1.1. Single-unit implant-retained crown restoration for missing mandibular second premolar.



Figure 1.2. Three-unit fixed partial denture that replaced two mandibular premolars and one molar in the mandibular right posterior quadrant. This prosthesis was supported by two endosseous, osseointegrated implants.

in conventional fashion from an autopolymerizing acrylic resin and cemented to the abutment (Figure 1.13). The key feature in this protocol is that the immediate provisional restoration should not have centric or eccentric occlusal contacts.

ABUTMENTS

Over the past 10–15 years, implant manufacturers have introduced various types of abutments that were designed for use in partially edentulous patients (Keith and others



Figure 1.3. Five-unit tissue-integrated prosthesis. In addition to replacing the maxillary right cuspid, lateral and central incisors, and the maxillary left central incisor, this prosthesis also replaced a large portion of the maxillary anterior alveolus (bone and soft tissue).



Figure 1.4. Immediately after implant placement surgery, this patient was discharged with instructions not to wear his preexisting prosthesis for at least the next 2 weeks.



Figure 1.5. These five implants were uncovered, and transmucosal abutments were placed by the surgeon. The abutment screws were torqued to 20 Ncm with a torque driver.

1999). Individual, single-unit implant restorations may be either screw- or cement-retained to the underlying abutments and/or implants. Cement-retained crowns have several advantages over screw-retained crowns. The most



Figure 1.6. Clinical anterior view with definitive maxillary complete denture and mandibular fixed hybrid prosthesis in place.



Figure 1.7. These healing abutments were placed immediately after maxillary implant surgery. The soft tissues were sutured around the healing abutments and would heal consistent with the shapes of the healing abutments.



Figure 1.8. These five implants were placed immediately after the remaining mandibular teeth were extracted. An alveolectomy was done after the extractions in order to obtain the necessary restorative space as well as making it easier and more predictable to drill the osteotomies.



Figure 1.9. Temporary cylinders (Implant Temporary Cylinders, Biomet 3i, Palm Beach Gardens, FL) were attached to the abutments with laboratory screws. Autopolymerizing acrylic resin was used to attach the cylinders to the immediate fixed prosthesis.



Figure 1.10. This is the occlusal view of the mandibular immediate fixed prosthesis prior to definitive finishing, polishing, and insertion of the prosthesis.



Figure 1.11. An implant was placed into the edentulous site of the missing maxillary right central incisor. Immediately after the implant was placed, an interim abutment (PreFormance Post®, Biomet 3i, Palm Beach Gardens, FL) was selected and placed onto the implant with a try-in screw. PreFormance Post (PFP454) as received from the manufacturer (inset).



Figure 1.12. The interim abutment was prepared outside of the patient's mouth, and the requisite interocclusal clearance and retention/resistance form for use as an abutment for a cement-retained crown was obtained.



Figure 1.13. The provisional restoration, without centric and eccentric occlusal contacts, was cemented onto the interim abutment. This patient was asked to refrain from chewing, biting, and otherwise using the implant and interim abutment for the next 8 weeks.

important advantage may be that there is no longer a need to have screw access openings that facilitate access to abutment screws in the occlusal or facial surfaces of implant crown restorations (Figure 1.14). However, in the event that abutments or crowns have to be repaired, cement-retained crowns are not as easily retrieved as screw-retained crowns (Figure 1.15).

Dental implant manufacturers have responded to the demands of clinicians, laboratory technicians, and the general public with greater choices and variations in implant restorations. One of the keys to successful long-term implant restorations is the stability of the implant/abutment connection. Both internal and external implant/abutment connections have proven to be successful in clinical use (Krennmair and others 2002; Drago, 2003). According to Finger and others (2003), there are at least

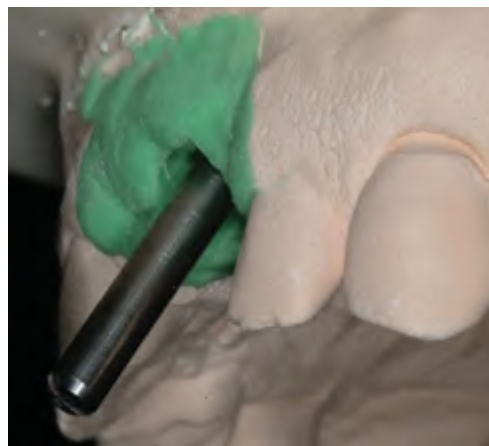


Figure 1.14. Master cast with laboratory abutment screw in place that demonstrates a screw access opening in the gingival third of the implant restoration's facial surface.



Figure 1.15. Occlusal view of the palatal surface of two implant-retained crowns replacing a maxillary left first premolar and maxillary left cuspid. If either crown needs to be replaced or repaired, a clinician would simply remove the composite resin restorations to obtain access to the abutment screws. However, the access restorations may interfere with the occlusion involving the opposing dentition.

20 different implant/abutment connection designs that have been approved by the Food and Drug Administration for sale in the United States.

ABUTMENT SELECTION

Selection of appropriate implant abutments can be confusing for both restorative dentists and dental laboratory technicians. In addition to the technical specifics associated with abutment selection, there are a myriad number of abutment choices within each dental manufacturer's inventory. With the significant number of implant restorative components available as noted above, it may be stated that there is increased difficulty and confusion in choosing the most appropriate abutment for a given clinical situation.

The abutment selection process may be divided into six separate steps (Drago and Lazzara 2009). This suggested protocol can be used for any dental implant system and in edentulous and partially edentulous situations:

1. Implant/abutment connection internal/external
2. Implant restorative platform (mm)
3. Emergence profile of healing abutments 5, 6, 7.5 mm
4. Soft tissue depth of peri-implant tissues (mm)
5. Implant angulation facial/lingual
mesial/distal
6. Interocclusal distance (mm)

This abutment selection protocol will be used throughout this textbook.

SURGICAL GUIDES

Conventional

Surgical guides are templates that transfer information regarding tooth position(s) to the surgeon prior to implant placement (Mizrahi and others 1998; Weinberg and Kruger 1998; Koyanagi 2002). It has been demonstrated that restorative dentists are responsible for determining the position of the replacement teeth in the implant prosthesis. This may involve the location of a single implant in an edentulous space for a single-implant restoration (Figures 1.16 and 1.17); multiple teeth with multiple implants (Figure 1.18); or the difference between the designs for a fixed partial denture versus a removable partial or complete denture (Figure 1.19).

After the treatment plan has been determined, surgical guides may be made from diagnostic casts, wax patterns,

and/or preexisting prostheses. They may be made from vacuum/heat-formed plastic (Figure 1.20), or from auto- or heat-cured acrylic resin (Figure 1.21).

Holes may be placed into surgical guides by restorative dentists, dental laboratory technicians, or surgeons (Figure 1.22). The location of the hole is usually determined by the surgeon. A limitation of this protocol is that it does not give the surgeon any directional indication once the drill is centered within the hole. This limitation may be compensated for with drill guides or guide tubes fitted into surgical guides (Figure 1.23).



Figure 1.17. Occlusal view of an implant in the maxillary left central incisor site that was placed into the available alveolar bone. However, the implant was palatal to the optimal implant position for prosthetic replacement of the missing tooth. This resulted in a cantilevered crown restoration and could result in long-term implant/abutment connection complications, including screw loosening and possible screw fracture.



Figure 1.16. The implant in the maxillary left central incisor edentulous site was placed optimally with the use of a surgical guide and resulted in a restoration with natural, aesthetically pleasing contours.



Figure 1.18. These implants were placed optimally M/D and F/L. However, the implant replacing the maxillary left central incisor was not placed deep enough in the apical direction, consistent with optimal replacement of the missing tooth or with the apical positions of the other implants and remaining teeth.

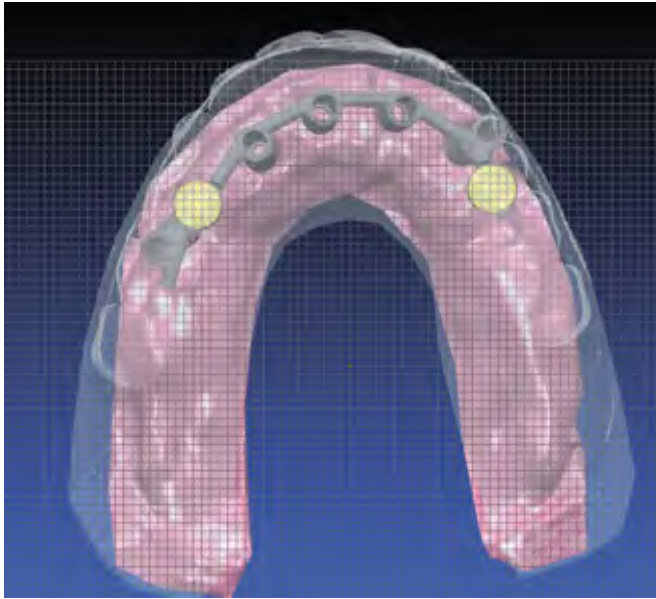


Figure 1.19. This is a computer-aided design (CAD) design for a maxillary computer-aided design/computer-aided manufacturing (CAD/CAM) milled bar. The wax denture was scanned and overlayed the maxillary edentulous ridge. Note the distance from the labial surfaces of the maxillary anterior teeth to the implants (7+ mm). This indicated that the patient required a relatively great degree of lip support from the labial flange of the denture and the denture teeth. This was also a contraindication for replacing the missing teeth with a porcelain-fused-to-metal fixed partial denture.



Figure 1.21. This surgical guide was made in clear, autopolymerizing acrylic resin by duplicating the patient's existing mandibular complete denture. The flanges were adjusted to minimize interferences with the mucoperiosteal flaps during surgery.

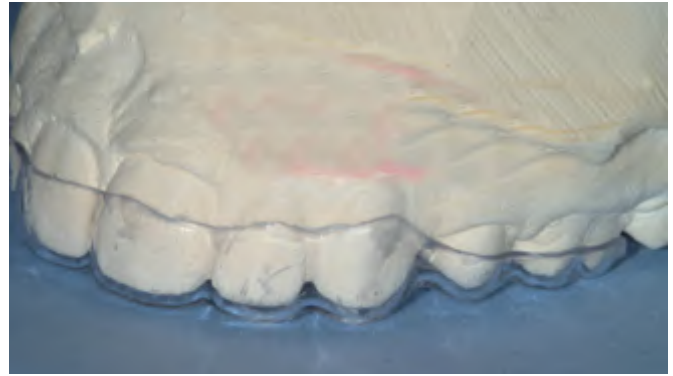


Figure 1.20. This surgical guide was fabricated from a 2-mm sheet of thermoplastic resin (Bio Cryl®, Great Lakes Orthodontics, Chicago, IL). This guide was actually trimmed incorrectly in that the apical portion of the guide did not incorporate the location of the gingival margins of the natural or artificial teeth in the maxillary left anterior quadrant. This eliminated a key dimension for the surgeon in determining the vertical location of the implants.

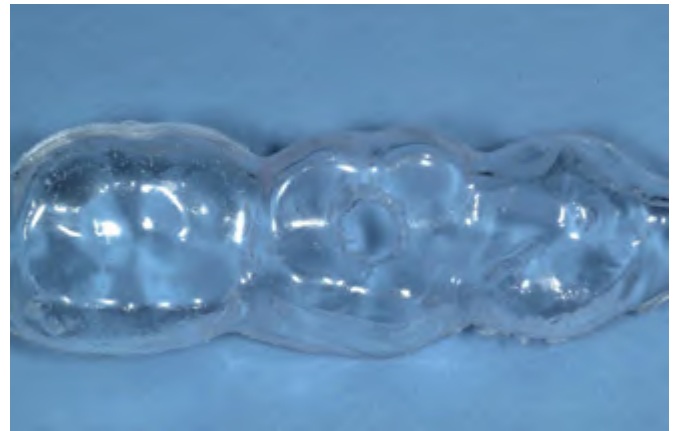


Figure 1.22. This surgical guide was made in anticipation of an implant replacing the mandibular left first molar with the material used in Figure 1.20. The surgeon placed a hole into the guide in the middle of the central fossa of the guide corresponding to the first molar.



Figure 1.23. This surgical guide features guide tubes (Stent Guide Tubes, SGT25, Biomet 3i, Palm Beach Gardens, FL) that were placed into the surgical guide by the surgeon, consistent with the planned location of the implants in the mandibular right posterior quadrant. The tubes provided the surgeon with proper angulation for the drills and osteotomies.

Computer Generated

Parel and Triplett (2004) first described a new interactive imaging program that allowed computed tomography (CT) images to be used to virtually place dental implants into edentulous sites in edentulous jaws. These data would then be used to fabricate precise surgical guides and interim or definitive prosthesis at the time of implant placement. They described a protocol where CT images in a

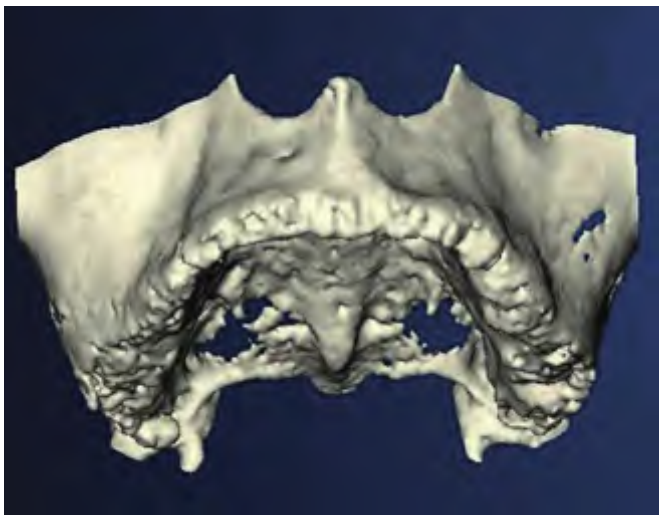


Figure 1.24. This is a reformatted computed tomography image of one patient's edentulous maxillae. Note the detail relative to the topography of the edentulous jaw.

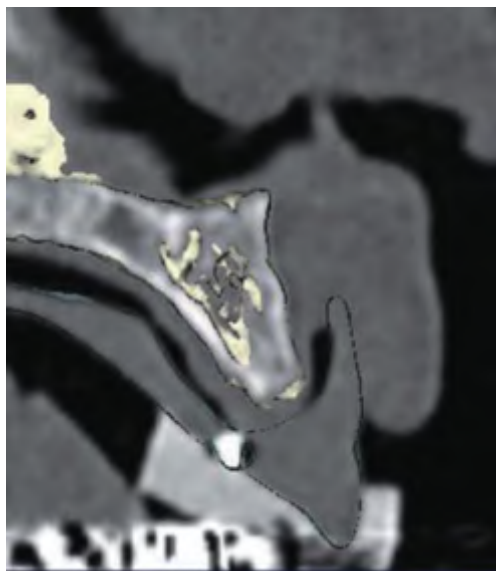


Figure 1.25. This is a cross-sectional oblique slice of the reformatted computed tomography scan in Figure 1.24. This view allowed the surgeon and prosthodontist to precisely identify the amount of bone available for implant placement and how the planned site related to the location of the teeth in the prosthesis.

three-dimensional image-based program (Oralim, Medicine NV, St. Niklaas, Belgium) were used for patients in planning and placing dental implants. As a result of their preliminary study, Parel and Triplett (2004) concluded that interactive computer imaging allowed for precise planning of implant positions and that these images could be used for fabrication of surgical guides and definitive prostheses prior to the actual surgery (Figures 1.24–1.28).

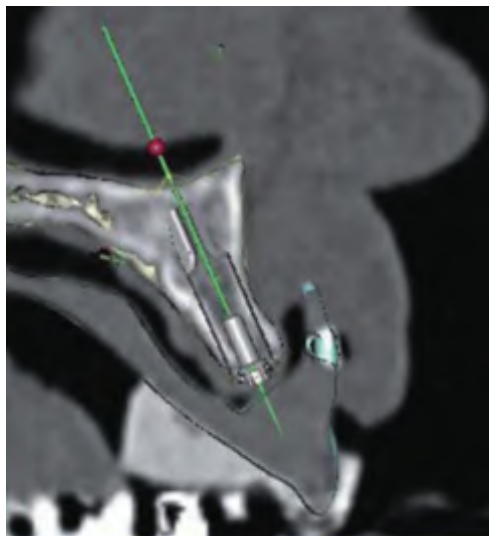


Figure 1.26. This cross-sectional oblique reformatted image identified the precise location of the implant within the alveolus and how it related to the location of the teeth in the prosthesis. In this slice, the screw access opening was lingual to the facial surface of the tooth in the prosthesis.

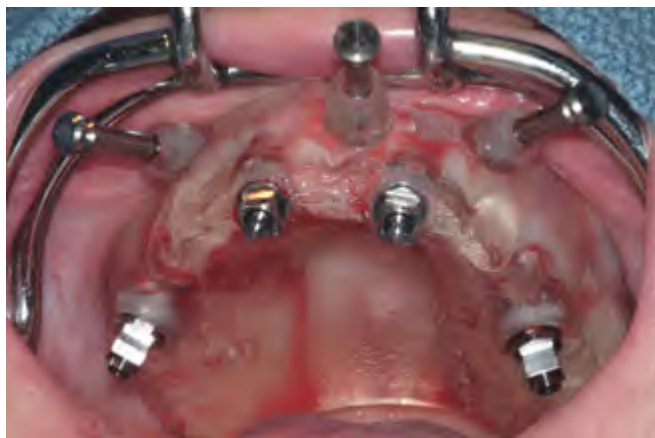


Figure 1.27. This clinical photograph was taken prior to removal of the computer-generated surgical guide used to place the maxillary implants. The surgical guide was held in place with three horizontal stabilizing screws. (Surgeon: Dr. Tim Durtsche, LaCrosse, WI)



Figure 1.28. This clinical photograph was taken with the maxillary prosthesis in place.

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Chapter 2: Mandibular Two-Implant Overdenture

INTRODUCTION

The retention and support of mandibular complete dentures with dental implants have proved to be beneficial for patients and dentists (Naert and others 1994, 1997; Engel and Weber 1995; Petropoulos and others 1997). Various methods have been used and described in order to retain overdentures to dental implants (Petropoulos and others 1997; Fromentin and others 1999; Williams and others 2001). Mandibular implants have become a successful and predictable treatment modality (Batenburg and others 1998; Feine and others 2002).

The use of dental implants as freestanding overdenture abutments will not eliminate dentures from rotating on an axis connecting the implants during function. Some authors have suggested that this rotation may have an influence on the success or failure of the implant-supported overdenture (Naert and others 1994; Payne and Solomons 2000). Other authors have demonstrated that position and retention mechanisms of mandibular implants retaining overdentures have little influence on the clinical success or failure of the prostheses (Oetterli and others 2001). Although placement of dental implants and bars in the anterior mandible parallel to the mandibular hinge axis may be favorable, Oetterli and others (2001) failed to demonstrate any significant advantages.

There has been significant research relative to overdenture attachments: nonsplinted stud-type attachments (Fromentin and others 1999), paired tests of splinted and unsplinted attachments (Setz and others 1998), and assessments of multiple splinted and nonsplinted attachments (Svetlize and Bodereau 2004). In a laboratory photoelastic study, Ochiai and others (2004) reported that alterations in the design of palatal coverage in edentulous maxillae produced a greater load transfer effect and more concentrated stress differences around the supporting implants than the specific selection of overdenture attachments (Hader bar with ERA [Sterngold Dental LLC, Boston, MA] attachments, nonsplinted Zaag direct abutments, and nonsplinted Locator Abutments [Zest Anchors Inc., Escondido, CA]) (Ochiai and others 2004).

Williams and others (2007) studied retentive capacities of extraoral prostheses that were retained by Hader bars with

three clips or three Locator attachments and found that the Locator attachments were correlated with higher retention values as well as with higher peri-implant stresses compared with the Hader bar-and-clip attachment design. Retention decreased and then stabilized after multiple insertions and removals (Williams and others 2007). Chung and others (2004) also studied retentive capabilities of multiple overdenture attachments and found that peak load-to-dislodgement measurements ranged from 3.68 to 35.24 N. ERA gray attachments demonstrated the greatest retention, with a peak load-to-dislodgement of 35.24 ± 1.99 N. Less retention was recorded for the Locator LR white, SpheroFlex ball (Preat Corp., Santa Ynez, CA), Hader bar and metal clip, and ERA white systems. The Locator LR pink attachment demonstrated still less retention, with a load-to-dislodgement of 12.33 ± 1.28 N. The lowest dislodging loads and strains were recorded for the Shiner magnet, Maxi magnet, and Magnedisc magnet attachments. They concluded that the attachment systems evaluated should be grouped into high (ERA gray), medium (Locator LR white, SpheroFlex ball, Hader bar and metal clip, ERA white), low (Locator LR pink), and very low (Shiner magnet, Maxi magnet, Magnedisc magnet) retention characteristics (Chung and others 2004).

The last consideration in selection of overdenture attachment systems is their potential impact on long-term prosthetic maintenance. Bar attachments for implant overdentures are subjected to mechanical forces that may result in fractures. The fractures may be a result of design of the bars and/or miscalculation of the occlusal forces involved for a particular patient. Bar fractures may occur at the rigid connectors of the interabutment areas or in the cantilevered areas (Figures 2.1 and 2.2). Goodacre and others (1999), in a literature review of clinical complications in implant prosthodontics, identified multiple etiologies including insufficient metal thickness, inferior solder joints, excessive cantilever lengths, inadequate strength of alloys, parafunctional habits of patients, and incorrect framework design.

New technology (computer-aided design/computer-aided manufacturing [CAD/CAM]) eliminates problems associated with castings by milling frameworks from solid blocks of titanium alloy (Drago and Del Castillo 2006) (Figures 2.3 and 2.4).



Figure 2.1. Clinical occlusal view of a fractured maxillary cast framework for an overdenture 18 months post insertion. Note the size of the solder joint in the upper portion of the photograph, as well as the multiple areas of surface porosity.



Figure 2.2. Laboratory measurement of the fractured framework seen in Figure 2.1. Note that the height (3 mm) and width (6 mm) of the framework appears to be within the requirements for satisfactory clinical use. Also note the size of the porosity that could not be visualized during the clinical and laboratory procedures because it was inside the casting.

CLINICAL PATIENT PRESENTATION

A 54-year-old female patient presented to the author with a chief complaint, "I can't wear my lower denture anymore." She had been edentulous in both jaws for approximately 25 years and had worn three sets of complete dentures. The most recent dentures were constructed about 3 years prior to the first clinical appointment (Figure 2.5).

The physical examination revealed that the dentures were not aesthetically pleasing. The maxillary denture had minimal retention, was unstable, and had an inadequate satisfactory posterior palatal seal. There was inadequate lip support; the vertical dimension of occlusion was decreased and unacceptable to the clinician and patient. The patient was not happy with the amount of teeth displayed while smiling or at rest (Figure 2.6). The mandibular denture was stable but exhibited little retention. There was a Class I occlusion in centric occlusion. The patient used denture adhesive inside her mandibular denture.

The intraoral examination revealed a maxillary edentulous ridge with moderate anterior/posterior and vertical resorption. The edentulous mandible exhibited severe vertical and buccal/lingual resorption, with a high and active floor of the mouth. There was a minimal amount of keratinized tissue remaining (Figure 2.7).

The panoramic radiograph demonstrated adequate bone height and width for possible implant placement in the mandible (Figure 2.8). In the presence of severe resorption or if a patient wished for a fixed hybrid prosthesis with five or more implants, a computed tomography (CT) scan would be indicated to assess the three-dimensional locations of the inferior alveolar and mental nerves, as well as the cross-sectional widths of the mandible in potential implant sites (Figures 2.8 and 2.9).

DIAGNOSIS

The following diagnoses were made:

1. Edentulous maxillae with moderate resorption
2. Edentulous mandible with severe resorption
3. Ill-fitting dentures

This patient was classified as Class III as per the American College of Prosthodontists Classification System of Complete Edentulism (McGarry and others 2002).

ASSESSMENT

In light of the severe mandibular resorption and ill-fitting dentures, it was the author's (C.D.) opinion that simply remaking both dentures would not be acceptable. The patient desired increased function and did not want to use denture adhesives for either denture. She presented with reasonable anatomy in the edentulous maxillae, and a new denture should be able to provide the requisite function, retention, stability, and aesthetics. In order to satisfy the patient's demands in the edentulous mandible, dental implants would be necessary. The benefits and limitations of two implants for use as abutments for a mandibular

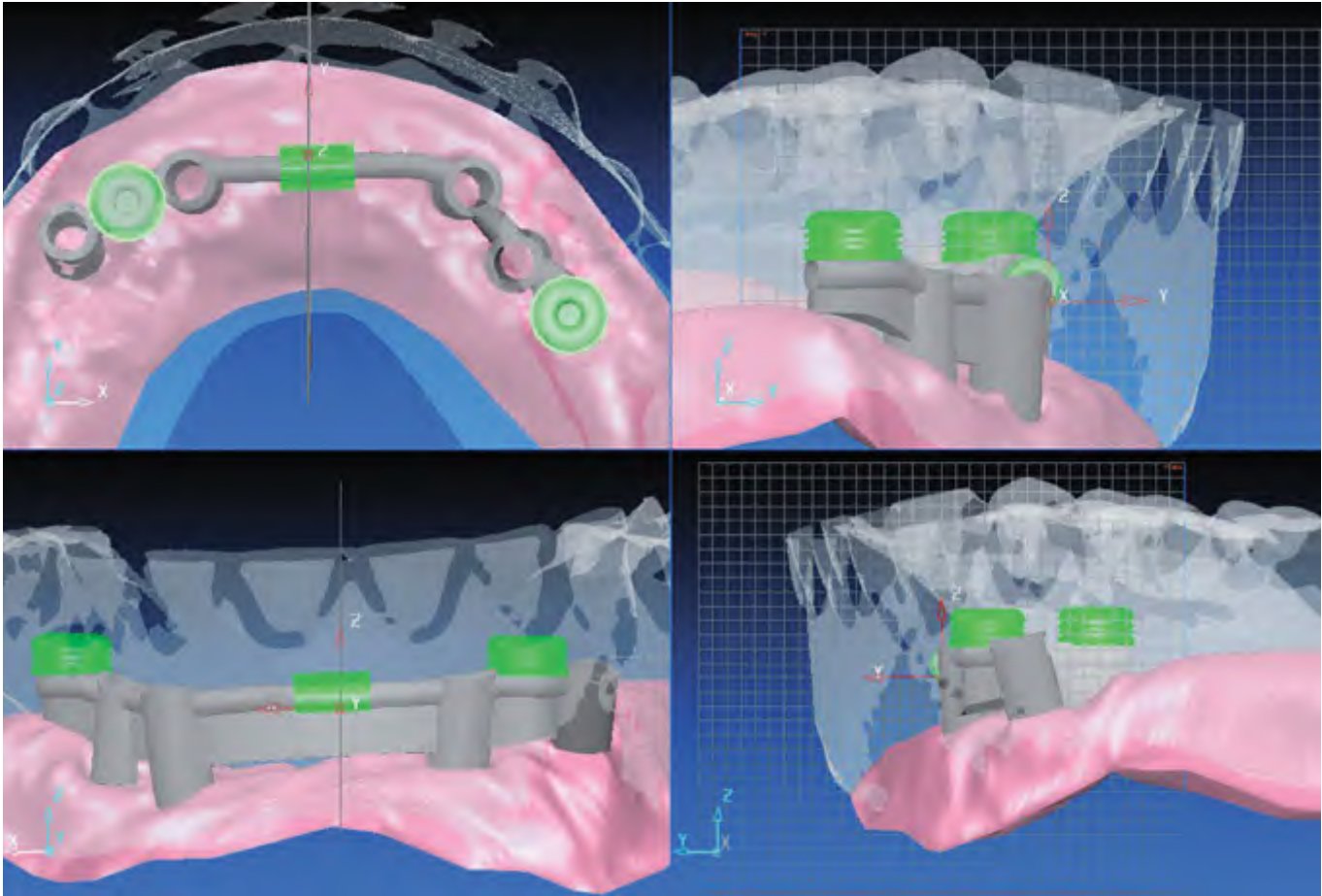


Figure 2.3. A CAD/CAM maxillary implant-retained framework. Four different views are presented in this figure. After a framework has been designed, multiple JPEG images are sent to the dental laboratory technician for review. Frameworks are not milled until the dental laboratory technician approves a given design (Architech PSR®, Biomet 3i, Palm Beach Gardens, FL).



Figure 2.4. This is the CAD/CAM maxillary framework as designed in Figure 2.3.



Figure 2.5. Clinical photograph of the patient as she originally presented to the author, with the original dentures in place. She was not pleased with the amount of tooth showing during smiling.



Figure 2.6. Clinical photograph of the patient at rest. Note the lack of vermilion border of the upper lip that was displayed with the patient at rest.

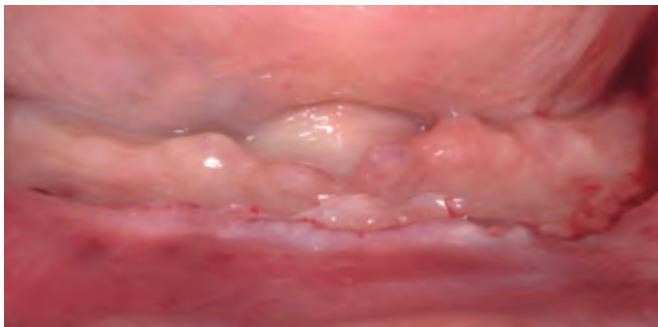


Figure 2.7. Preoperative clinical image of the patient's edentulous mandible. Note the severe horizontal and vertical resorption.

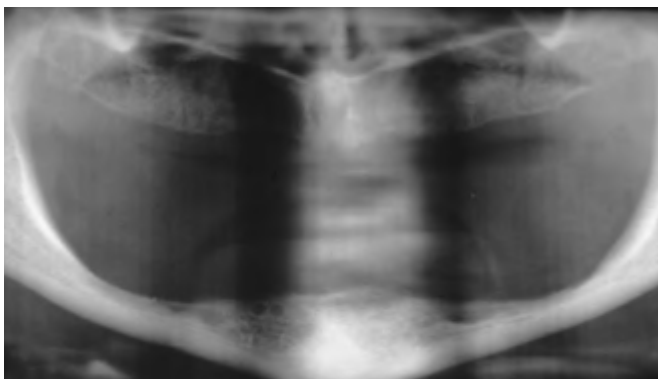


Figure 2.8. Preoperative panoramic radiograph that demonstrated the patient's edentulous jaws. There was adequate mandibular bone height and width to potentially accommodate dental implants in the anterior mandible.

overdenture versus five or six implants for use as abutments for a fixed hybrid prosthesis were discussed, and the patient elected to proceed with the two-implant option.

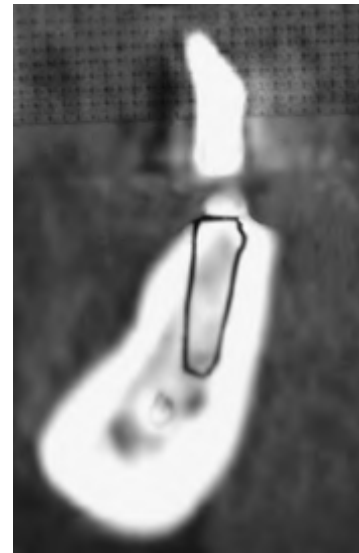


Figure 2.9. This is an image of a CT cross section of this patient's edentulous mandible. The CT scan was made with a duplicate denture in place, where the denture teeth were coated with barium sulfate. The radiopacity at the top of the image corresponds to an incisor, and its position relative to the potential implant site can be assessed. This location had adequate bone available for implant placement.



Figure 2.10. Laboratory image of the mandibular diagnostic cast made from a well-extended alginate impression.

A treatment plan was developed that included outpatient surgery for the placement of two implants in the anterior mandible. Arrangements were made for a surgical consultation.

DIAGNOSTIC CASTS

Well-extended alginate impressions were made and poured in dental stone (Figure 2.10; Table 2.1).

TABLE 2.1. Work Order for Diagnostic Casts, Custom Impression Tray, and Surgical Guide

1. Disinfect the enclosed alginate impressions.
2. Pour the enclosed alginate impressions in dental stone as per manufacturer's instructions.
 - a. Weigh the stone and measure the water volume.
3. Vacuum spatulate.
4. Let the stone harden.
5. Draw a line 2mm short of the buccal and lingual reflections.
6. Block out any undercuts with wax.
7. Use light-cured resin to fabricate a custom impression tray.
8. Trim and polish the peripheral borders of the impression tray.
9. Identify the location of the two mandibular anterior implants and create holes corresponding to the locations in the impression tray.
10. Fabricate the surgical guide with a 0.5-mm-thick plastic sheet (Biostar®, Great Lakes Orthodontics Ltd., Tonawanda, NY).
11. Place two holes where indicated on the occlusal surface of the mandibular edentulous ridge.
12. Return the casts, custom impression tray, and surgical guide.



Figure 2.11. Laboratory image of the surgical guide on the mandibular cast. The planned location for the right anterior implant was identified by a hole made with a #8 round bur.

The tentative locations of the implants were marked on the mandibular cast, and a surgical guide was fabricated (Figure 2.11).

The implants were placed according to the treatment plan and healing/osseointegration occurred uneventfully. The size and shape of the healing abutments had been predetermined preoperatively by the author and surgeon.



Figure 2.12. Clinical image of the healing abutments in place approximately 8 weeks post implant placement. The implants were stable and the soft tissues had healed. A small amount of calculus was visible on the mesial surface of the right healing abutment.

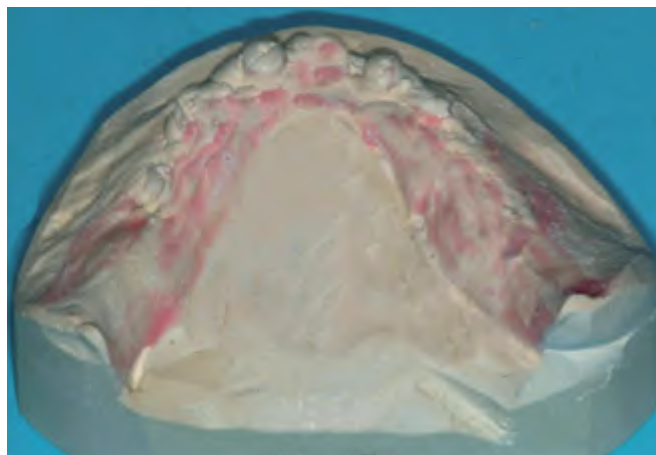


Figure 2.13. Mandibular diagnostic cast with anterior healing abutments in place.

CUSTOM IMPRESSION TRAYS

Healing occurred uneventfully. The soft tissues healed, and the implants became osseointegrated (Figure 2.12). Alginate impressions were made for construction of new diagnostic casts and custom impression trays. The healing abutments were accurately impressed within the impression and replicated on the diagnostic cast (Figure 2.13).

In anticipation of the overdenture abutments and impression copings being placed clinically, in the mandibular diagnostic cast, the healing abutments were blocked out with a small amount of a 50/50 mixture of plaster of paris and fine pumice (Figure 2.14). This block out would provide adequate clinical space for the pick-up impression procedures. A custom impression tray was made from light-cured resin (Triad, Dentsply International, York, PA) (Figure 2.15).



Figure 2.14. The healing abutments were blocked out with a 50/50 mixture of plaster of paris and fine pumice prior to construction of the custom impression tray. This mixture maintains its shape and is easily carved with a green handle knife.



Figure 2.15. Occlusal view of the custom denture impression tray with holes corresponding to the location of the two mandibular anterior implants.

DEFINITIVE INTRAORAL IMPRESSION

Clinically, the healing abutments were removed and replaced with Locator® Abutments (Zest Anchors Inc.) (Figure 2.16). Locator Abutments were used because they are easy to use, come in multiple heights (1-mm increments, 1–6mm), are resilient, and are long lasting. Pick-up impression copings specific for the Locator Abutment system were placed onto the abutments intraorally, and the definitive impressions were made using polyvinyl siloxane impression material (Figure 2.17).

MASTER CAST

Laboratory analogs were placed into the intaglio surfaces of the impression copings inside the impression (Figure 2.18), and the impression was boxed and poured in dental stone (Tautin 1983) (Figures 2.19 and 2.20).

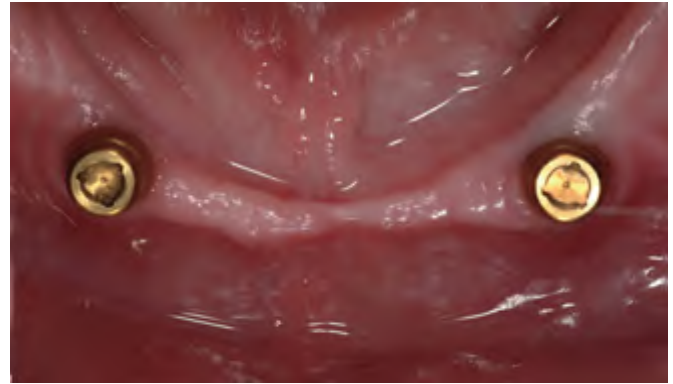


Figure 2.16. Clinical occlusal view with two Locator Abutments in place.



Figure 2.17. Pick-up impression copings (LAIC1), specific for Locator Abutments, were placed onto the abutments prior to making the definitive impression. The inset is a close-up view of the impression coping/abutment interface.



Figure 2.18. Intaglio view of the definitive mandibular impression. The abutment analog was placed into the impression coping on the patient's right side. Abutment analog (LALA1) (inset).

Boxing definitive impressions before pouring preserves the extensions, as well as the thicknesses, of the denture impression borders, controls the form and thickness of the cast base, and conserves dental stone (Rudd and others 1980). A typical mandibular, boxed impression requires



Figure 2.19. Occlusal view of the boxed mandibular impression. Heavy body alginate was used as the boxing medium. Magnetic boxing strips were used instead of wax.



Figure 2.20. Occlusal view of mandibular master cast with two Locator analogs in place. The implant analogs replicated the positions of the implants in the mouth and will serve as overdenture abutments in conjunction with the mandibular occlusion rim.

200 g of stone. Several methods and materials are available for boxing impressions; heavy-body alginate impression material and a magnetic strip were used in this procedure (Tautin 1983).

RECORD BASES

As early as 1929, authors have discussed the importance and requirements of accurate record bases. Keyworth (1929) stated that the purposes of record bases are as follows:

1. To act as carriers for occlusion rims for jaw relation records
2. To hold the teeth in wax for the wax denture try-in
3. To check the accuracy of the preliminary jaw relation records

Record bases and occlusion rims transfer the clinical information relative to the vertical dimension of occlusion, lip support, incisal display at rest and while smiling, and the centric relation or centric occlusion position of the edentulous mandible to the edentulous maxillae. Jaw relationships, midlines, occlusal plane, location of the lip line and maxillary cuspids, amount of horizontal and vertical overlap, and the desired support of the cheeks and lips can be indicated on the record bases and occlusion rims. To a large degree, the success of the prosthodontic portion of the treatment plan depends on the accurate communication of this clinical information to dental laboratory technicians.

Record bases should (Elder 1955):

1. Adapt to the denture-bearing areas and extensions of the jaws as the definitive dentures will
2. Be rigid and dimensionally stable
3. Be constructed to carry the teeth in the wax dentures
4. Be simple, predictable, and inexpensive to construct
5. Be able to be removed from the cast without abrasion and be able to take advantage of desirable undercuts (Tucker 1966)

In this case, the record bases were made from light-cured resin. The author (C.D.) prefers wax on maxillary record bases for the occlusion rim and makes the initial jaw relation record with gray modeling compound on the mandibular record base (Kerr Manufacturing Co., Romulus, MI) (Figure 2.21; Table 2.2).

The initial dimensions of the maxillary occlusion rim have been described as follows (Jamieson 1956):

1. Average distance from the maxillary labial sulcus to the maxillary central incisal edge should be 22mm.
2. Posterior vertical height of the maxillary occlusion rim should be 6–8mm.
3. Distance from the incisive papilla indentation to the labial surface of the maxillary central incisor should be 8mm.
4. The curvature of the maxillary occlusion rim should correspond to the overall curvature of the maxillary arch.
5. Occlusion rims should be approximately 8mm wide.



Figure 2.21. Laboratory facial view of the maxillary and mandibular casts mounted on a simple hinge articulator. Note that the maxillary midline was carved into the occlusion rim, the occlusal plane was consistent with the orientation of the occlusal plane clinically, and there was no horizontal overlap between the record bases anteriorly.

TABLE 2.2. Work Order for Construction of Maxillary and Mandibular Record Bases, Maxillary Occlusion Rim

1. Draw lines at the depth of the vestibules on both casts.
2. Block out any undercuts with wax.
3. Paint tinfoil substitute (Modern Foil, Modern Materials, St. Louis, MO) on the cast.
4. Use light-cured resin to fabricate maxillary and mandibular record bases; place the resin up to the above lines.
5. Polymerize as per the manufacturer's instructions.
6. Finish and polish the peripheral borders. Take care to preserve the extent and thicknesses of the record bases' borders.
7. Place a wax occlusion rim onto the maxillary record base. The occlusal aspect of the occlusion rim should measure approximately 22mm to the depth of the labial vestibule in the central incisor region.
8. The posterior occlusal height of the maxillary occlusion rim should measure approximately 8mm from the occlusal surface to the crest of the edentulous ridge in the first molar regions.
9. The curvature of the maxillary occlusion rim should follow the curvature of the edentulous maxillary ridge.
10. The occlusion rim should be approximately 8mm wide.
11. Do not place any wax on the mandibular record base.
12. Return both record bases.

ARTICULATOR MOUNTING

The author made the jaw relation records clinically and returned the casts and record bases to the laboratory (Table 2.3). In this case, the maxillary and mandibular casts were mounted in the center of a simple hinge articulator, with the occlusal plane consistent with the orientation of the clinical occlusal plane, at the predetermined vertical dimension of occlusion with the patient in centric relation. Mounting stone should set quickly and hard, with minimal dimensional changes; it should be strong and separate cleanly from the casts after using a separating medium (Mounting Stone, Whip Mix Corporation, Louisville, KY) (Table 2.4). It is essential that the mounting stone not damage the cast or the articulator (Figure 2.22). The midline of the maxillary occlusion rim was placed consistent with the center of the patient's face and with the location of the incisal guide pin (Figure 2.23).

WAX DENTURES

Arranging and articulating denture teeth is, perhaps, the most important element for patient satisfaction in prosthodontics, including implant overdenture treatment. It is obviously important in dental aesthetics and phonetics, but it is also important in generating optimal facial aesthetics because of the support that the denture teeth and denture flange give to the lips and cheeks. It is therefore critical to set and place the artificial teeth in the same or similar locations that the natural teeth occupied prior to their loss. This is especially critical in cases where the edentulous maxillae have resorbed superior and posterior

TABLE 2.3. Articulator Mounting of the Master Casts

1. Use mounting stone to articulate the casts. (Table 2.4).
2. The incisal guide pin should be set at zero.
3. Place the mandibular record base onto the mandibular master cast.
4. Mount the mandibular cast and mandibular record base in a simple hinge articulator with the
 - a. midline centered;
 - b. cast in the middle of the articulator; and
 - c. occlusal plane horizontal.
5. Place the maxillary record base onto the maxillary cast.
6. Occlude the interocclusal records and casts together.
7. Lute the casts together as per your mounting protocol.
8. Mount the maxillary cast consistent with the interocclusal record.

TABLE 2.4. Characteristics of Mounting Stone

Vendor	Whip Mix Corporation
Item	Mounting Stone
Product number	Inquire
Quantity	02917 (white; 11 kg [25lb] carton) 33197 (white; 22kg [50lb] carton) 18740 (blue; 11 kg [25lb] carton) 33200 (blue; 22kg [50lb] carton) 18730 (white; 100g package) 18731 (blue; 100g package)
Compressive strength	Wet: (1 hour) 4600 psi (32MPa) Dry: (48 hours) 8500psi (59MPa)
Working time	2–3 minutes
Set time	5 minutes
Indication for use	Mounting casts to articulators
Liquid/powder ratio	26mL/100g
Setting expansion	0.08%

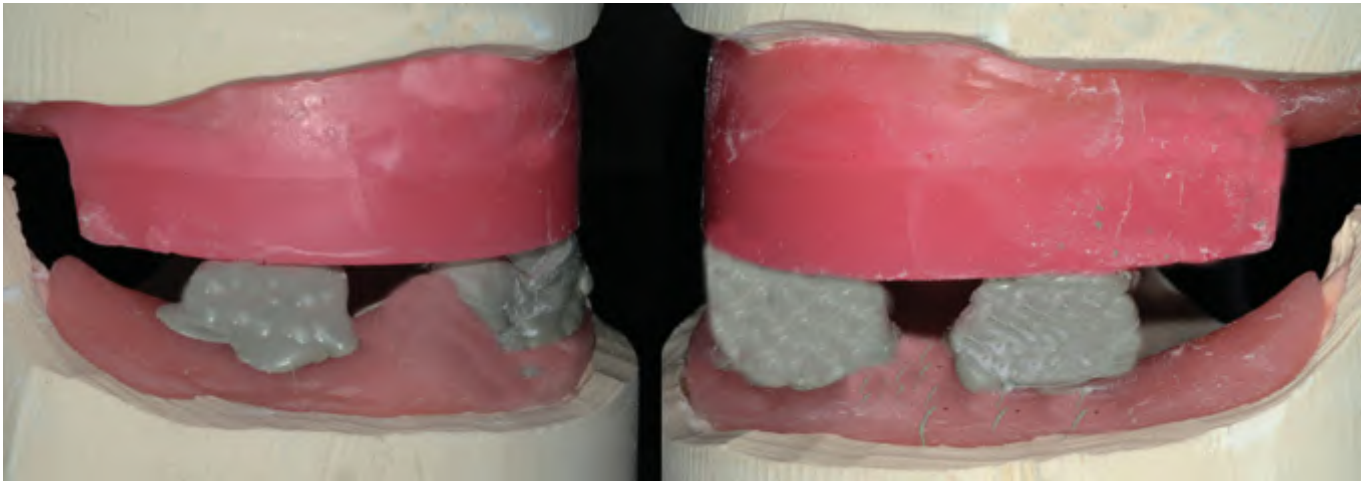


Figure 2.22. Right and left lateral laboratory views of the maxillary and mandibular casts mounted on a simple hinge articulator. This was a centric relation articulator mounting.

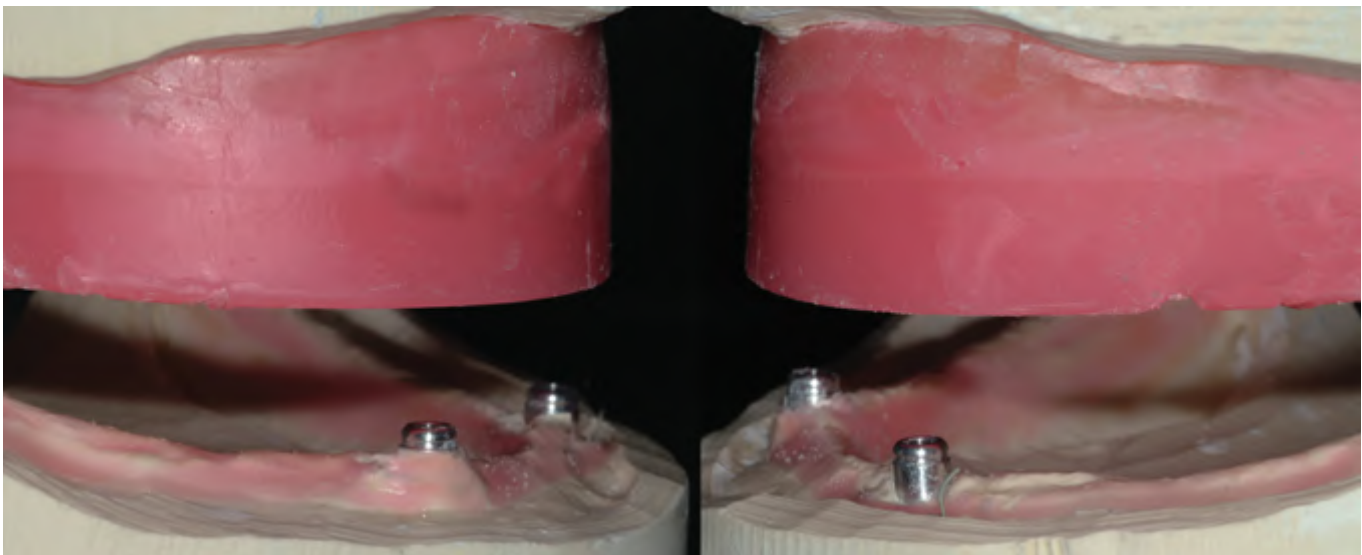


Figure 2.23. Right and left lateral laboratory views of the maxillary and mandibular casts mounted on a simple hinge articulator. The mandibular record base was removed. Note the location of the abutment analogs relative to the facial surface of the maxillary occlusion rim and the amount of available interocclusal distance for setting the mandibular denture teeth.

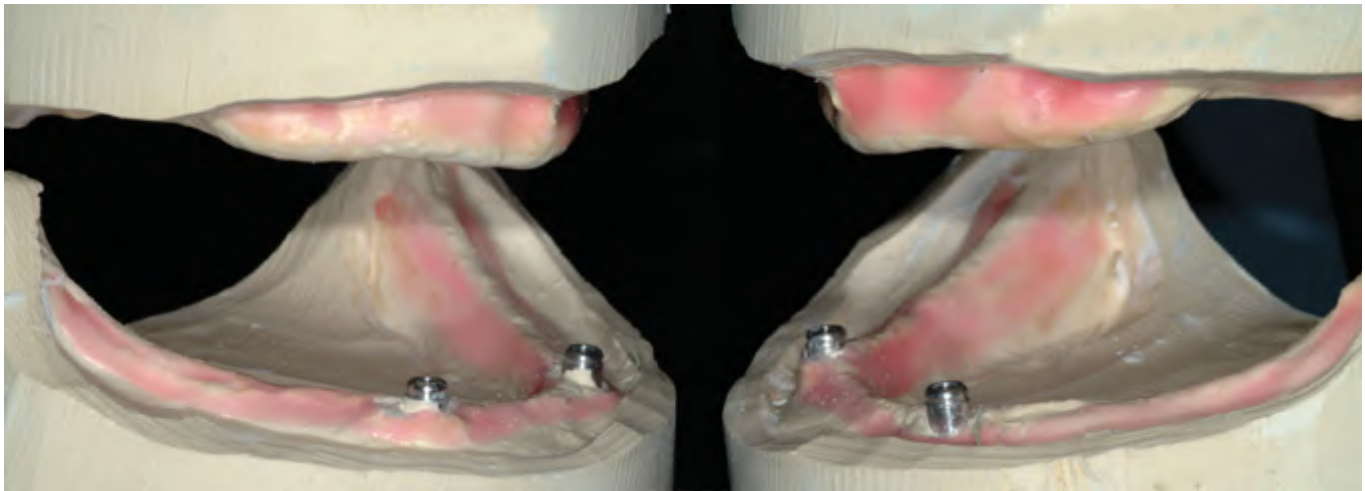


Figure 2.24. Right and left lateral laboratory views of the maxillary and mandibular casts mounted on a simple hinge articulator. Record bases have been removed. Note the location of the abutment analogs relative to the anterior segments of the edentulous maxillae. The maxillae have resorbed posterior and superior relative to the edentulous mandible. The maxillary anterior teeth, to be set consistent with the location of the facial surface of the occlusion rim, need to be placed significantly anterior to the residual edentulous ridge.

and the edentulous mandible has resorbed anterior and inferior (Figure 2.24).

It is also critical to set the artificial teeth in positions consistent with the contours of the occlusion rim and record bases and to not use the edentulous ridges as guides for tooth placement. In setting maxillary anterior teeth, one primary objective is to provide a balance between aesthetics and phonetics. Anterior teeth set according to the location of an edentulous ridge will generally be set too far palatal and will interfere with optimal phonetics.

In this case, the anterior teeth were set consistent with the contours of the maxillary occlusion rim (Figure 2.25) (Justi Imperial®, Bolton Dental Manufacturing, Cambridge, Ontario, Canada). This particular manufacturer fabricates denture teeth in 39 upper anterior molds, 10 upper anterior molds, 17 lower posterior molds, in 18 shades. Asymmetries were placed into the setup, consistent with the patient's aesthetic requirements. There were minimal vertical and horizontal overlaps between the maxillary and mandibular anterior segments. Proper positioning of the maxillary cuspid teeth is extremely important for both aesthetics and occlusion. Both of the maxillary cuspids were slightly rotated, highlighting the mesiolabial portions of the teeth.

Careful attention was paid to the gingival contours around the artificial teeth: the clinical crown heights of the maxillary central incisors were waxed longer than the clinical crown heights of the maxillary lateral incisors, but shorter than the clinical crown heights of the cuspids. The gingival contours also reflected the gingival contours of maxillary



Figure 2.25. The denture teeth were arranged consistent with the patient's aesthetic demands, jaw relationship, and remaining anatomy. In this laboratory facial view, subtle differences were established between the contralateral incisors and cuspids, with a small space waxed into the area between the maxillary left central and lateral incisors. The gingival contours of the anterior maxillary teeth were waxed consistent with the gingival contours seen in the natural dentition.

anterior teeth in that the greatest heights of the clinical crowns of anterior teeth are distal to the midfacial surfaces of the teeth (McVane and Ettinger 1991; Levine and Katz 2003).

Generally speaking, the most common problems associated with waxing dentures for try-in are related to covering



Figure 2.26. In this laboratory lateral view of the waxed dentures, the right and left posterior teeth were placed in maximum intercuspation, and the occlusal plane followed the plane established by the maxillary occlusion rim.

too much of the denture teeth with wax, excessive adjustment of the cervical portions of the denture teeth to facilitate placement onto the record base, failing to develop anatomical contours within the denture bases, and using wax that may be discolored from overheating. Dental laboratory technicians should be cognizant of these pitfalls as they make for unaesthetic wax dentures and can be disappointing to restorative dentists and patients.

Many types of tooth forms are available for posterior teeth. This patient wished for an aesthetic, nonartificial-looking tooth arrangement. Cusped teeth were selected (Justi Imperial). The posterior teeth were set in maximum intercuspation consistent with the location of the occlusal plane recorded in the maxillary occlusion rim. Group function occlusion with balancing contacts in right, left, and protrusive positions was established (Figure 2.26). Two molars and one premolar were placed consistent with the location of the ascending border of the mandibular ramus. By decreasing the heights of the clinical crowns from the cuspids to the second molars, the gingival contours of the posterior teeth mimicked the gingival contours of natural teeth (Table 2.5).

The wax try-in was accomplished without incident. The patient approved of the aesthetics associated with the wax dentures, and the author (C.D.) confirmed the centric relation record. The patient wished to proceed with processing the dentures.

PROCESSING

After the wax dentures were returned to the dental laboratory for processing, the mandibular wax overdenture was

removed from the cast. The titanium housings were placed onto the abutment analogs in the cast (Figure 2.27). Windows were cut into the record base to make sure that the housings did not interfere with reseating the denture (Figure 2.28). The housings were blocked out again with the plaster/pumice mix, and the definitive waxing was completed (Figure 2.29).

The denture was sprued, consistent with an injection molding protocol for acrylic resin, and invested in denture flasks with dental stone (Eclipse Prosthetic Resin System, Dentsply International) (Figure 2.30).

The flask was placed into a hot water bath, and the wax was removed. The denture was processed with the Eclipse Prosthetic Resin System.

The mandibular overdenture was removed from the flask, but not from the cast. The areas over the attachment housings were identified, and the acrylic resin was removed with burs and a shell blaster. The plaster/pumice block out material was removed and both housings were completely exposed (Figure 2.31). Autopolymerizing acrylic resin (Lucitone 199® Repair Material, Dentsply International) was placed into the space between the housings and the processed overdenture using the sprinkle-on technique (Figure 2.32). The complex was placed into hot water (120°C) in a pressure pot at 10psi for 15 minutes.

This protocol was developed by the author (C.D.) to decrease the distortion and increase the likelihood of the overdenture going to place accurately (Drago and Gingrasso 2005).

TABLE 2.5. Work Order for Setting the Maxillary and Mandibular Denture Teeth

1. Use the enclosed artificial denture teeth.
2. Place the maxillary central incisors in positions with the incisal edges even with the occlusal surface of the occlusion rim.
3. Position the maxillary lateral incisors approximately 1 mm superior to the incisal edges of the maxillary central incisors.
4. Place the cuspids with the cusp tips even with the posterior occlusal plane of the occlusion rim.
5. The cusp tips of the maxillary cuspids should be palatal to the facial cervical third of the cuspids.
6. Set the mandibular anterior teeth consistent with a Class I occlusal relationship with the maxillary anterior teeth. Do not set the mandibular incisors parallel to each other. The long axes must be nonparallel to each other.
7. Place the maxillary first premolar with its long axis at right angles to the occlusal plane. Place the buccal and lingual cusps on the plane.
8. Do not set the maxillary second premolars.
9. Place the maxillary first molars so the mesiobuccal and mesiolingual cusps touch the occlusal plane.
10. Raise the distobuccal and distolingual cusps approximately 0.5mm from the occlusal plane.
11. Place the mesiobuccal cusp of the second molar approximately 1 mm from the occlusal plane.
12. Articulate the mandibular posterior teeth to have a Class I occlusal relationship with the maxillary posterior teeth.
13. Contour the baseplate wax immediately superior to the maxillary anterior teeth to produce a subtle bulge that corresponds to the free gingival margin of natural teeth.
14. Contour the wax above the maxillary cuspids to simulate maxillary cuspid eminences.
15. Develop a slight root prominence over the maxillary central incisors.
16. Develop a slight concavity above the roots of the maxillary lateral incisors.
17. Contour the anterior flange of the maxillary wax denture to produce a slightly convex effect.
18. Wax a gingival bulge immediately above the necks of the posterior teeth.
19. Carve a slight depression above the premolar teeth and extend it from the cuspid eminence anteriorly to the molars posteriorly.
20. Remove excess wax from around the necks of the teeth.
21. Return the wax dentures for try-in.



Figure 2.27. Titanium housings in place on the abutment analogs in the mandibular master cast.

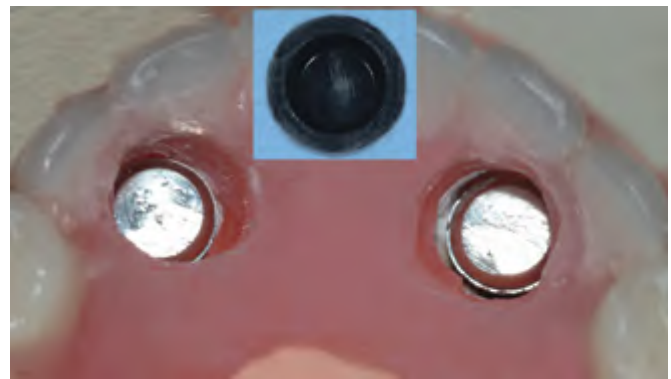


Figure 2.28. Laboratory occlusal view of the mandibular record base in place on the cast with the housings in place on the abutment analogs. The inset demonstrates the intaglio surface of the titanium housing. Windows were cut into the record base to insure that the record base completely seated around the housings.



Figure 2.29. Laboratory occlusal view of the mandibular waxed overdenture prior to spruing and processing.

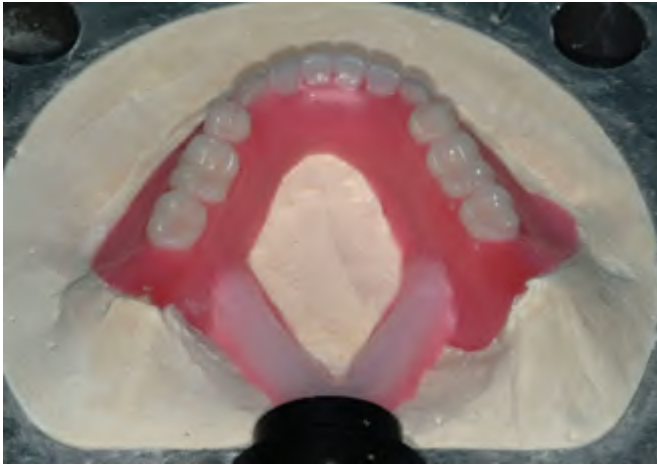


Figure 2.30. Laboratory occlusal view of the mandibular waxed overdenture, sprued and invested in the lower half of the denture flask.



Figure 2.31. Laboratory occlusal view of the mandibular overdenture after processing and removal of the acrylic resin that covered the housings.



Figure 2.32. Laboratory occlusal view of the mandibular overdenture after autopolymerizing acrylic resin had been placed to attach the housings to the processed overdenture.



Figure 2.33. Laboratory lingual view of the mandibular overdenture after it was finished and polished.



Figure 2.34. Laboratory intaglio view of the mandibular overdenture with the titanium housings in place. Arbitrarily, the pink retentive attachments with 3lb of retention were placed into the housings.

TABLE 2.6. Retention Strengths—Locator Nylon Replacement Males

(8524) clear:	5lb/2268 g
(8527) pink:	3lb/1361 g
(8529) blue:	1.5lb/680 g
(8547) green:	3–4lb/1361–1814 g
(8548) red:	1.5lb/680 g

The dentures were remounted with their original articulator mountings. The occlusion was adjusted consistent with final waxing: centric cusp/fossae contacts and working, balancing, and protrusive contacts. Both dentures were removed from their respective casts, finished, and polished in conventional fashion. Arbitrarily, pink retentive attachments were placed within the keepers inside the processed dentures (Figures 2.33 and 2.34; Table 2.6).



Figure 2.35. Anterior clinical view of the patient with prostheses in place, in centric occlusion.



Figure 2.36. Anterior clinical view of the patient smiling with appropriate incisal display, lip support, and aesthetic results.

INSERTION

The maxillary complete denture and mandibular implant-retained overdenture were inserted in conventional fashion (Figures 2.35 and 2.36).

The following clinicians and dental laboratory technicians were responsible for the treatments illustrated in this chapter:

Surgeon: Dr. C. Garry O'Connor, LaCrosse, WI

Prosthodontist: Dr. Carl Drago, LaCrosse, WI

Dental Laboratory Technician: Andrew Gingrasso, LaCrosse, WI

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Chapter 3: Immediate Occlusal Loading—Maxillary Hybrid Prosthesis with Cast Metal Framework (The Columbus Bridge Protocol)

INTRODUCTION

It is well known that the jaws of edentulous patients undergo significant, irreversible resorptive changes after loss of the natural teeth (Atwood and Coy 1971; Tallgren 1972). These resorptive processes cause significant changes in the anatomy of the edentulous jaws, which may lead to problems in patients adapting to complete dentures. Long-term bone resorption can, in some instances, preclude implant placement (Gelb 1993). For optimal restoration of function and aesthetics in edentulous patients with anatomical limitations, additional surgeries and technically demanding prosthetic procedures may be required. These additional procedures increase morbidity and may result in decreased overall success of implant treatment. Treatment times and costs will certainly be increased.

Initially, loading dental implants was governed by a strict protocol (Brånemark and others 1977; Albrektsson and others 1986). Immediate loading of dental implants in the 1960s resulted in fibrous encapsulation of the implants, implant mobility, and loss of implants (Linkow and Charchee 1970). Under certain circumstances, immediate occlusal loading (IOL) of endosseous implants was found to be as efficacious as the unloaded healing protocol described above. Schnitman and others (1990, 1997) reported on immediate fixed interim prostheses supported by Brånemark implants in the treatment of mandibular edentulism. These researchers reported that the 10-year cumulative survival rate (CSR) for all of the implants (IOL and nonloaded healing protocols) was 93.4%. Life table analysis of the immediately loaded implants demonstrated a 10-year CSR of 84.7%. The 10-year CSR for the nonloaded implants was 100%. These two sets of data were statistically significant ($P = 0.022$).

Tarnow and others (1997) reported on IOL in edentulous maxillae and mandibles with both machined and altered implant surfaces. Edentulous maxillae are remarkably different from edentulous mandibles on both macroscopic and microscopic levels. Maxillary bone has a lower density than mandibular bone between the mental foramen (Brånemark and others 1977; Albrektsson and others 1986). Trabecular bone is softer and therefore it is more difficult to achieve high implant stability at implant place-

ment, which many consider to be the most important factor for the process of osseointegration (Friberg and others 1991). In soft bone, undersizing the osteotomies and selecting implants of differing shapes, lengths, and diameters may help overcome anatomical limitations and permit the attainment of high primary stability (Adrianssens and Herman 2001). Insertion torque of at least 40Ncm has been suggested as the minimum value acceptable for immediate implant loading (Vanden Bogaerde and others 2003), although there is debate on this subject when multiple, splinted implants are compared with single, unsplinted implants (Del Fabbro and others 2006). Brunski (1993) has hypothesized that micromovement of implants within their osteotomies can have a negative impact on osseointegration. Others have suggested that precise surgical and prosthetic protocols have to be followed for predictable osseointegration (Skalak 1983; Galli and others 2008; Testori and others 2008).

Tealdo and others (2008) recently published a study that evaluated the 12-month implant survival after immediate loading of four to six implants with fixed screw-retained prostheses in edentulous maxillae. They called this protocol the Columbus Bridge Protocol. Twenty-one patients, edentulous or with remaining teeth to be extracted in maxillae, received four to six implants ($n = 111$). The patients were restored with screw-retained fixed provisional prostheses supported by palladium alloy frameworks within 24 hours after surgery. Insertion torques for implants were at least 40Ncm. Implants, grouped as tapered or cylindrical screws, were placed into healed bone or extraction sockets. Implants were also classified as either vertical or off-angle. Definitive prostheses were placed after a mean healing time of 18 weeks. Radiographic examinations were made at the time of placement of provisional prostheses and 12 months later. Between groups, the bone resorption was compared using two-way analysis of variance (ANOVA) ($\alpha = 0.05$). The mean follow-up time for all of the patients was 20 months (range: 13–28 months). The cumulative implant survival rate at the 12-month follow-up visits (after surgery) was 92.8%; the prostheses survival rate was 100%. No significant differences were found between the survival of tapered or cylindrical screw-type implants placed in postextraction sockets versus those in healed edentulous sites or between vertical and off-angle placed implants. Eight implants failed during the first

3 months, five of which were the most distal implants. The mean reduction in marginal bone height over the 12-month observation period was 0.84 mm (95% confidence interval [CI]: 0.68–0.99 mm). Tealdo and others (2008) concluded that at the 12-month follow-up period in their study, four to six implants were sufficient to successfully support fixed implant screw-retained prostheses in the edentulous maxillae of 21 patients.

The Columbus Bridge Protocol was the basis for the clinical and laboratory treatment illustrated in this chapter.

CLINICAL PATIENT PRESENTATION

A 45-year-old female presented to Dr. Tealdo's office with a chief complaint, "My teeth hurt. They are unattractive. I want them removed and replaced with teeth that do not come out" (Figures 3.1–3.9). This patient presented with a high lip line, uneven occlusal/incisal planes, and her right and left posterior maxillary segments were visible. The gingival margins were uneven across the maxillary incisors; there was a significant amount of root exposure noted especially in the right anterior quadrant.



Figure 3.1. Clinical preoperative image of the patient with a full smile. Note the length of the teeth and the amount of root surfaces exposed secondary to chronic periodontal disease.



Figure 3.3. Clinical preoperative image of the patient at rest, with her lips together. The preoperative contours of the upper and lower lips were satisfactory and did not have to be changed.

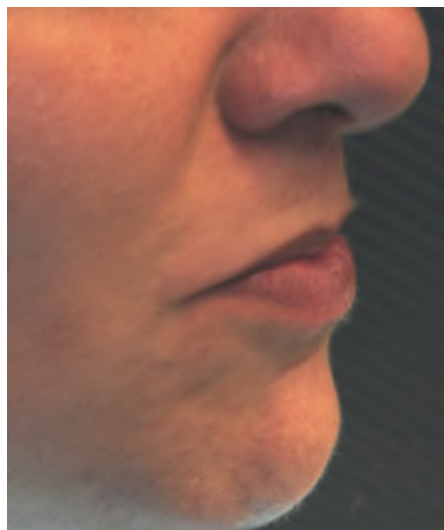


Figure 3.2. Clinical preoperative profile image of the patient in centric occlusion. The vertical dimension of occlusion and lip support were considered to be acceptable by the patient and the clinicians.



Figure 3.4. Clinical preoperative occlusal view of the maxillary dentition.



Figure 3.5. Clinical preoperative occlusal view of the mandibular dentition.



Figure 3.6. Clinical intraoral, preoperative anterior view of the patient in centric occlusion. Note the significant amount of root surfaces exposed secondary to periodontal disease. The missing soft tissues will be replaced with pink acrylic resin to make the heights of the clinical crowns the appropriate size.



Figure 3.7. Clinical intraoral, preoperative view of the patient's right posterior segments in centric occlusion. The occlusal plane was relatively flat and horizontal.



Figure 3.8. Clinical intraoral, preoperative view of the patient's left posterior segments in centric occlusion. The occlusal plane was relatively flat and horizontal.



Figure 3.9. Preoperative panoramic radiograph immediately prior to the surgical appointment. Note the significant amount of bone loss secondary to periodontal disease.

TABLE 3.1. Classification of Maxillary Sinus Defects and Recommended Protocols for Implant Placement

Classification	Residual Bone Height (mm)	Surgical Protocol	Graft Material
A	≥10	Classical drilling protocol	
B	7–9	Osteotome and immediate implant placement	
C	4–6	Lateral approach, graft material, delayed or immediate implant placement	Autologous, xenograft, synthetic
D	1–3	Lateral approach, grafting, delayed implant placement	Autologous, xenograft, synthetic

The patient's past medical and dental history had no significant findings, with the exception of long-term dental neglect. The patient did not present with any medical findings that were thought to negatively impact surgical and prosthetic treatment. This patient admitted to being compliant with past oral health care professionals' recommendations in terms of brushing, flossing, and 4-month recall appointments.

DIAGNOSES

The following diagnoses were developed:

1. Chronic generalized severe periodontitis (Type IV) with generalized moderate gingival recession
2. Class I malocclusion with dysfunction
 - a. Crossbite between the maxillary left lateral incisor and mandibular left cuspid
3. Multiple teeth with irreversible pulpitis
4. Dental caries

ASSESSMENT

This patient's dentition was considered to have a hopeless prognosis. None of the teeth were identified as having sufficient support to act as abutments for fixed or removable partial dentures. The patient ruled out maintaining any of the teeth for use as overdenture abutments. She did not want any type of removable prostheses for any length of time, nor did she wish to go without artificial replacements for any length of time. The possibility of extractions with immediate placement of implants and IOL was discussed, and she decided to proceed with this treatment option. However, she also refused to consider bone grafts to the maxillary sinuses prior to posterior implant placement. She wished for the maxillary dentition to be treated first.

Lack of bone in the posterior maxillae has been problematic relative to having enough bone in which to place

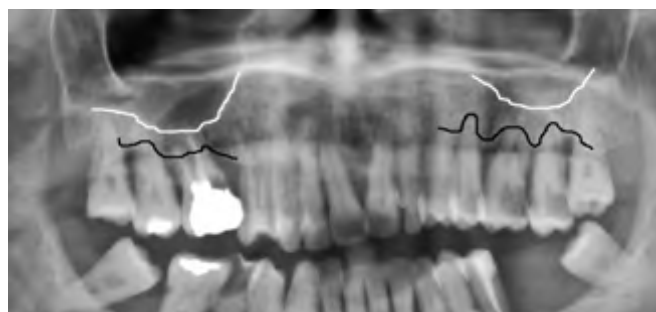


Figure 3.10. Preoperative panoramic radiograph with the floors of the maxillary sinuses (white) and the approximate preoperative locations of the crestal bone (black).

endosseous implants. When there is inadequate bone height below a maxillary sinus, various bone grafting protocols have been developed, based on the amount of residual bone. In 1987, Misch presented four bone augmentation protocols based on the amount of available bone below the maxillary sinus. He classified four different amounts of bone and recommended bone augmentation procedures according to the amount of bone remaining. Misch's classifications included SA-1 for vertical bone heights >12mm; SA-2 for vertical bone heights between 10 and 12mm; SA-3 for vertical bone heights from 5 to 10mm; and SA-4 for vertical bone heights <5mm.

In 1996, a consensus conference on maxillary sinus grafting protocols issued recommendations for selecting a surgical approach based on the amount of residual bone height (RBH) (Jensen and others 1998). Their classifications are described in Table 3.1. The case illustrated in this chapter was classified as Class C (4–6mm) on the left side; Class D (1–3mm) on the right side (Figure 3.10). If the patient's wishes were to be satisfied, the only way the clinicians could treat this patient was to use tilted implants, parallel to the anterior wall of the maxillary sinuses posteriorly, as per Maló and others (2005) (Figure 3.11).

To obtain natural aesthetics, clinicians must carefully consider the patient's entire facial structure, not just the teeth and perioral tissues. In this case, the patient was generally pleased with the size and shape of her natural teeth. She was displeased with the three-dimensional positioning of the teeth and the lack of gingival tissues surrounding the teeth. These concerns needed to be taken into account in developing the aesthetics of the implant prosthesis.

DIAGNOSTICS

The initial screening radiograph was the panoramic film. However, in order to obtain more detailed information, the

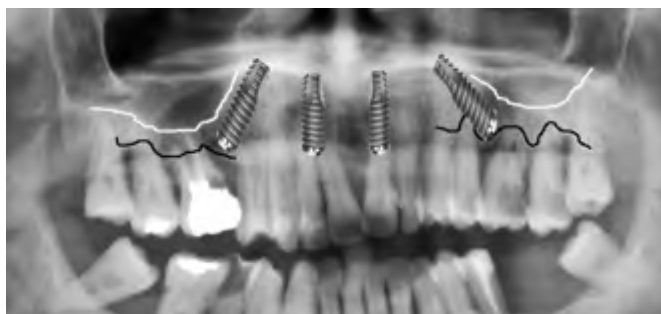


Figure 3.11. Preoperative panoramic radiograph with the floors of the maxillary sinuses (white) and the approximate location of the crestal bone immediately after posterior tooth extractions (black). Implants have been placed into tentative positions, based on the available bone. The posterior implants are tilted in order to increase their lengths.

clinicians ordered a full series of periapical radiographs (Figures 3.12–3.14). These films confirmed the significant, generalized bone loss originally identified in the panoramic radiograph. At this point, the clinicians could have ordered computed tomography (CT) scans to precisely identify the pathology and bone dimensions in three dimensions (Rosenfeld and others 2006). CT scans were not thought to be required to adequately assess this particular patient.

Additional photographs were taken to assess the relationships among the gingival margins, tentative bone levels, and exposure of the posterior teeth smiling. The amount of teeth visible in the posterior segments with the patient smiling can be critical relative to the overall aesthetic results obtained with implant-retained prostheses (Figure 3.15).

A centric relation (CR) record was made with one layer of baseplate wax (Figure 3.16). There are two positions related to occlusion: CR and centric occlusion (CO—maximum intercuspation). CR is thought to be a bone-to-bone relationship between the mandibular condyles and the glenoid fossae of the maxillae. CO is defined as a tooth-to-tooth relationship and may be independent of CR. One can have a CO position between unmounted diagnostic casts. According to Phoenix and others (2003), in more than 90% of all persons, CR and maximal intercuspation position do not coincide. When the positions are different, CO will always be anterior to CR. The differences may range from tenths of a millimeter to 5mm or more, with 1- to 2-mm differences as the most common. Regardless of the occlusal scheme to be employed by the dentist and dental

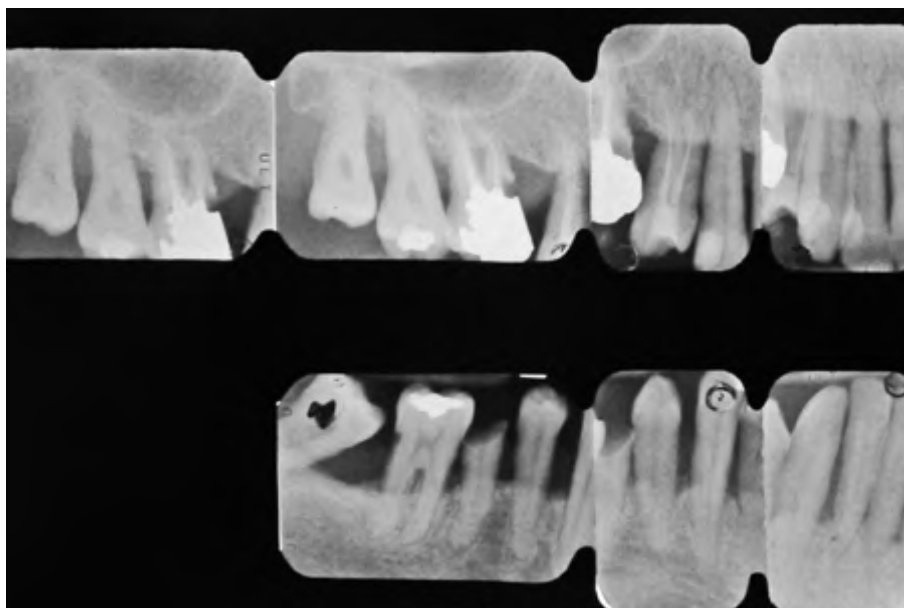


Figure 3.12. Preoperative periapical radiographs of the right posterior quadrants.

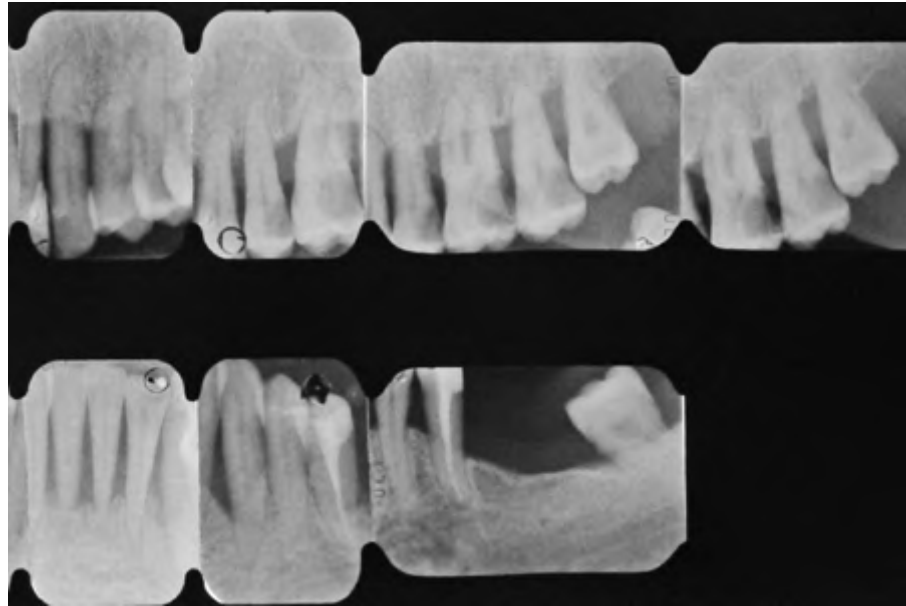


Figure 3.13. Preoperative periapical radiographs of the left posterior quadrants.

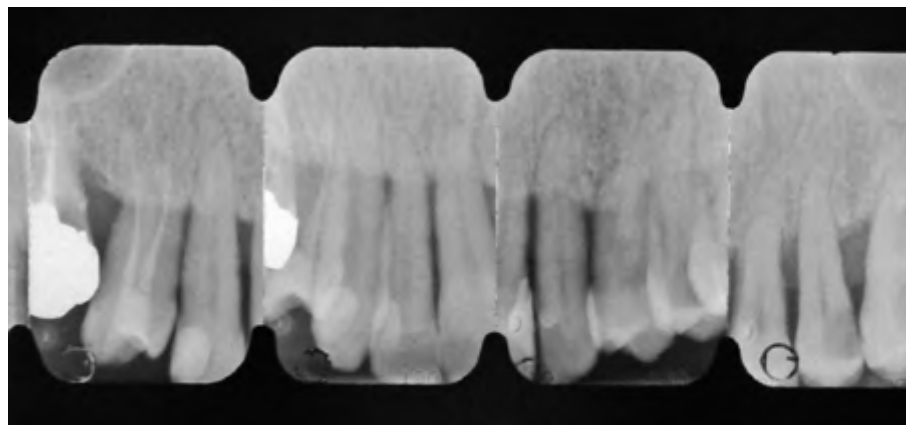


Figure 3.14. Preoperative periapical radiographs of the maxillary anterior quadrants.

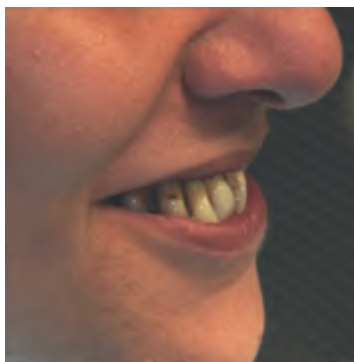


Figure 3.15. Preoperative clinical image of the patient, in profile, smiling. Note the length and amount of the teeth that are visible in the right anterior lateral quadrant. The excessive tooth lengths will be compensated for with the gingival colored acrylic resin of the prosthesis.



Figure 3.16. Intraoral image of the one layer of baseplate wax centric relation record.



Figure 3.17. Intraoral image of the three-layer baseplate wax centric relation record that will be used in the fabrication of the processed acrylic resin guide.

laboratory technician, there must be harmony between these two positions.

An additional, 3-mm-thick wax interocclusal CR record was also made (Figure 3.17). This will be critical in developing the surgical guide.

The clinicians used wax as their recording material in spite of the known inaccuracies associated with wax interocclusal records (Schweitzer 1981). The casts could have been accurately articulated by hand and mounted in an articulator without any recording material because the patient had a significant number of teeth remaining (Phoenix and others 2003). There are a wide variety of materials available in making jaw relation records, including wax, modeling compound, accelerated dental stones, zinc oxide/eugenol (ZOE) impression pastes, and polyether and polyvinyl siloxane impression materials. Wax and modeling compound are easy to use and are reasonably accurate, but they are subject to distortion from the time the records are made clinically until the casts are mounted. Accelerated dental stones and ZOE impression pastes are extremely accurate, but they can be difficult to use intraorally. These latter materials are dimensionally stable and accurate; they also may be difficult to trim and are subject to fracture.

Polyether and polyvinyl siloxane impression materials are also extremely accurate and are also easy to use intraorally. These materials may be compressible and should be used in thin sections no thicker than 2mm. These two materials can be easily trimmed and have been proven to be dimensionally stable for extended periods (Thongthammachat and others 2002).



Figure 3.18. Laboratory photograph of the diagnostic casts, mounted on a hinge articulator with the one-layer wax centric relation interocclusal record in place. The vertical dimension of occlusion for this mounting was increased by approximately 1 mm.

ARTICULATOR MOUNTING

At this point, casts have to be mounted on an articulator. Dental articulators have been designed to perform a multitude of tasks associated with mandibular movements. The movements include rotating around a fixed, horizontal axis, as well as simulating lateral mandibular movements. Semiadjustable articulators have been designed with adjustable condylar paths, adjustable lateral condylar paths, and adjustable incisal guide tables. This was the type of articulator that was used in treating this patient.

A facebow transfer was not accomplished for this patient. Instead, the dental laboratory technician mounted the maxillary cast in the center of the articulator, horizontally, vertically, and right to left, with the dental midline centered with the incisal guide pin. The mandibular cast was mounted to the maxillary cast with the wax interocclusal record in place (Figures 3.18–3.20).

The casts were now ready to be adjusted in preparation for the surgery, which was to include extraction, alveolectomy, implant placement, and immediate restoration and function of the screw-retained implant prosthesis.

SURGICAL GUIDE

The Columbus Bridge Protocol calls for fabrication of the surgical guide at an increased vertical dimension of occlusion (Figure 3.21). The wax interocclusal record was



Figure 3.19. Laboratory photograph of the right side of the articulator mounting.



Figure 3.20. Laboratory photograph of the left side of the articulator mounting.

transferred from the mouth to the articulator and verified that the articulator mounting was accurate.

Since the vertical dimension of occlusion was not going to be changed with the interim prosthesis, it was not necessary to have a clinical try-in of any kind to verify the accuracy of the articulator mounting. It was imperative that the clinicians conveyed to the dental laboratory technicians the approximate amount of bone that was going to be removed subsequent to the extraction of the teeth, prior to implant placement. This information was transferred from the maxillary periodontal pocket measurements taken at the first clinical appointment (Figures 3.22–3.24).



Figure 3.21. Articulator mounting of the casts with the three-layer baseplate interocclusal record in place. This was the wax record, made intraorally at a vertical dimension that ensured the patient would be able to open far enough for adequate access to place the surgical guide and the surgical placement of the implants.



Figure 3.22. Clinical image of the periodontal probe on the distal surface of the maxillary left lateral incisor. With the patient under local anesthesia, the clinician penetrated the epithelial attachment with the periodontal probe until he touched the alveolar crest of bone. This depth was recorded, along with several other points, and transferred to the laboratory so that the appropriate amount of bone would be removed from the cast in anticipation of the clinical alveolectomy, prior to preparation of the osteotomy.

The incisal edges were to be reduced as per the patient's request. The tentative locations of the incisal edges were communicated by the clinicians to the dental laboratory technician by drawing blue lines on the incisal edges of the teeth on the cast (Figure 3.25). A silicone index was made that replicated the new positions of the incisal edges



Figure 3.23. Laboratory image of the maxillary diagnostic cast and a periodontal probe in the interproximal area between the maxillary left lateral incisor and the left maxillary cuspid. Arbitrarily, the clinician asked the dental laboratory technician to remove bone 3 mm apical to the alveolar crest identified in Figure 3.21. A black dot was placed on the buccal alveolar process approximately 5 mm apical to the free gingival margin of the maxillary left first molar. This was the tentative level of the alveolus post extraction and alveolectomy. The blue line is indicative of the base of the gingival sulci.



Figure 3.24. Laboratory image of a periodontal probe in the interproximal area between the maxillary right cuspid and lateral incisor. Arbitrarily, the clinician asked the dental laboratory technician to remove bone 3 mm apical to the tentative location of the alveolar crest that was to be established clinically after the extractions.

so that the positions could be transferred to the maxillary cast after the teeth were extracted and the bone was removed (in the laboratory) (Figure 3.26). The teeth and bone were removed according to the above parameters (Figure 3.27).



Figure 3.25. Laboratory image of the diagnostic casts after the clinical information had been transferred to the cast, but prior to tooth extractions and laboratory alveolectomy. The blue lines on the incisal edges of the maxillary anterior teeth are the tentative locations of the incisal edges of the denture teeth.



Figure 3.26. Laboratory image of the silicone index in place on both casts. This was made to facilitate the transfer of the incisal edge positions from the adjusted maxillary diagnostic cast to the denture setup prior to fabrication of the surgical guide.

The preselected denture teeth were set onto the cast as per the wishes of the patient and the clinical parameters concerning facial and dental midlines, occlusal/incisal planes, occlusal contacts with the mandibular teeth, and overall aesthetics (Figures 3.28–3.31).

A silicone impression was made of the wax denture that included some of the palate and the buccal and labial land areas of the maxillary cast (Figures 3.32 and 3.33). This

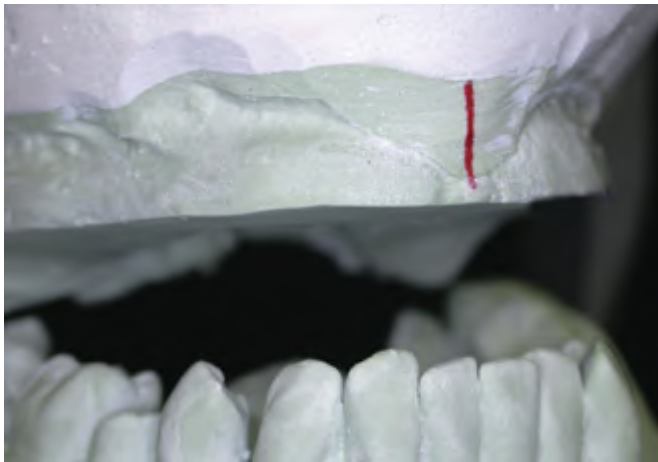


Figure 3.27. Laboratory image of the maxillary cast after the teeth were extracted and the alveolus was reduced in anticipation of the postoperative bone levels, prior to implant placement.



Figure 3.29. Laboratory right posterior image of the maxillary denture setup.



Figure 3.28. Laboratory anterior image of the denture setup. Note that the wax holding the teeth was not contoured for forming the denture base. The wax was used simply to hold the teeth in position for construction of the surgical guide.



Figure 3.30. Laboratory left posterior image of the maxillary denture setup. The maxillary left lateral incisor was placed optimally, which resulted in a crossbite with the mandibular left cuspid. The mandibular left cuspid would be adjusted at the time of the clinical insertion of the maxillary prosthesis.

impression was used to fabricate the surgical guide and had to be repositioned accurately on the cast.

Autopolymerizing acrylic resin was mixed as per the manufacturer's instructions, poured into the silicone impression, and repositioned accurately onto the prepared maxillary cast. The resin was allowed to set and was removed from the impression. It remained in position on the prepared maxillary cast (Figures 3.34 and 3.35).

A window was cut into the occlusal surface of the surgical guide from the right second molar to the occlusal surface of the left second molar with a large acrylic resin bur in a laboratory slow-speed handpiece (Figures 3.36 and 3.37). The surgical guide was contoured incisally to allow room for implant placement by removing portions of the incisal edges. The surgical guide was also contoured cervically to identify the locations of the cemento-enamel junctions (CEJs) of the artificial teeth (Figure 3.38).



Figure 3.31. Laboratory occlusal image of the maxillary wax denture setup.



Figure 3.32. Laboratory image of the occlusal surface of the silicone impression of the wax denture.

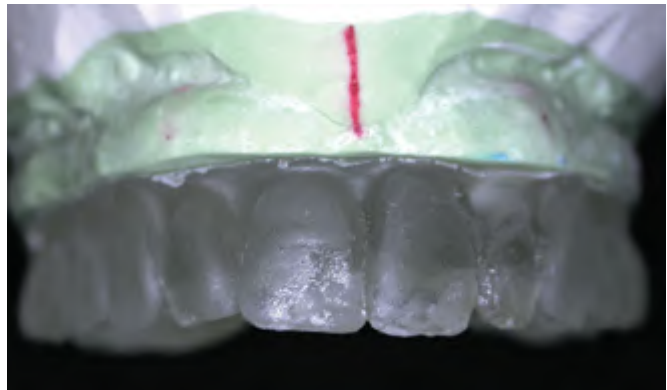


Figure 3.34. Laboratory labial image of the processed surgical guide on the diagnostic cast.



Figure 3.33. Laboratory image of the intaglio surface of the silicone impression of the wax denture. Note that the land area was recorded in the impression to facilitate accurate repositioning of the impression for fabrication of the surgical guide.

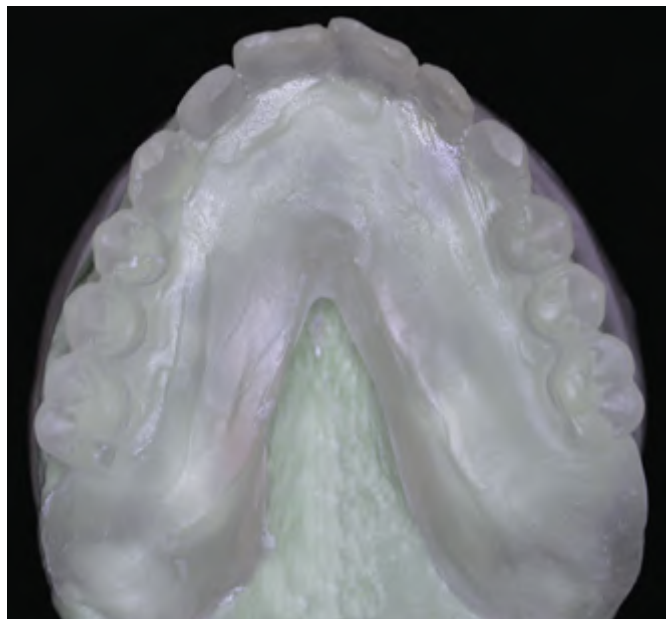


Figure 3.35. Laboratory occlusal image of the processed surgical guide on the diagnostic cast.



Figure 3.36. A large acrylic resin bur was used to cut a window into the occlusal surface of the surgical guide.



Figure 3.37. The window extended from the second molar on the right side to the second molar on the left side. It had to be large enough to accommodate implant drills and the handpiece during preparation of the maxillary osteotomies, as well as drivers to secure the abutments to the implants.

Autopolymerizing acrylic resin was mixed and applied to the occlusal, facial, and lingual surfaces of the teeth on the mandibular diagnostic cast. Care was taken to block out the lingual undercuts prior to the application of the acrylic resin; the resin was kept occlusal to the undercuts

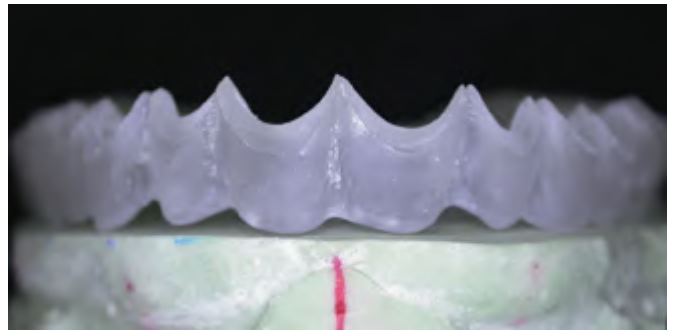


Figure 3.38. To facilitate optimal implant placement relative to the locations of the artificial teeth, the surgical guide was contoured to identify the CEJs of the artificial teeth. The incisal edges were contoured as well to facilitate the drills and the implant handpiece during the preparation of the osteotomies.



Figure 3.39. Laboratory image of the labial surface of the mandibular portion of the surgical guide. Lingual undercuts were blocked out with wax prior to fabrication of the guide. The labial and buccal undercuts were not engaged by the acrylic resin. This facilitated uncomplicated insertion of this portion of the guide into the mouth on the day of surgery.

on the facial and buccal aspects of the mandibular teeth (Figures 3.39 and 3.40).

The articulator was set at the vertical dimension established by the three-layer CR wax interocclusal record (Figure 3.41). The maxillary and mandibular portions of the surgical guide were positioned accurately onto their respective casts and luted together posteriorly with autopolymerizing acrylic resin (Figure 3.42). The anterior portion was accomplished next, and the resin was allowed to completely polymerize (Figure 3.43). The surgical guide was then removed from the cast, polished, and sterilized (Figure 3.44). It was now ready for use intraorally.

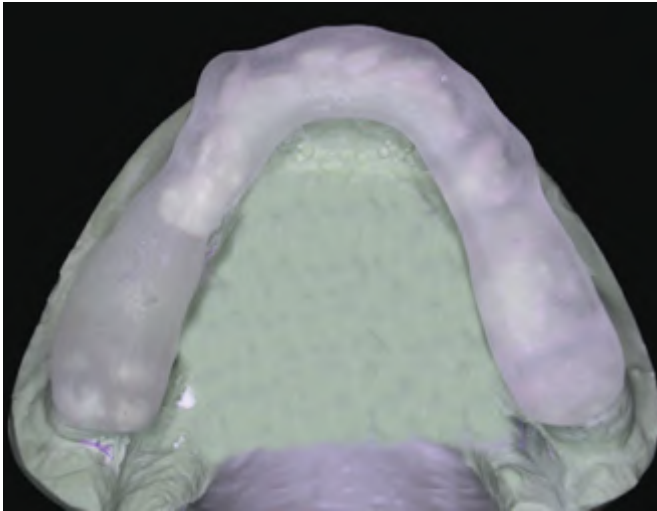


Figure 3.40. Laboratory image of the occlusal surface of the mandibular portion of the surgical guide. This surface was not polished in order to improve the bond to the acrylic resin of the maxillary portion of the surgical guide.



Figure 3.41. The surgical guide was made at the vertical dimension established with the three-layer wax centric relation interocclusal record.

The surgical guide provided the surgeon with information relative to the appropriate amount of bone removal in each extraction socket, the location of the dental and facial midlines, the location of the CEJs of the artificial teeth, and the approximate locations of the incisal edges of the artificial teeth. The surgical guide would be stabilized on the occlusal and incisal surfaces of the mandibular teeth, and thus ensure the accurate transfer of the above information.



Figure 3.42. Laboratory posterior image of the maxillary and mandibular portions of the surgical guide in place on their respective casts. Autopolymerizing acrylic resin was used to lute the maxillary and mandibular components together. The posterior segments were attached first.



Figure 3.43. Laboratory anterior image of the maxillary and mandibular portions of the surgical guide in place on their respective casts. Autopolymerizing acrylic resin was used to lute the maxillary and mandibular components together. The anterior segment was accomplished after the posterior segments had been attached.



Figure 3.44. Laboratory image of the surgical guide after it was removed from the diagnostic casts, prior to sterilization.



Figure 3.45. Clinical image of the patient on the day that she presented for the surgery.

SURGERY/IMPLANT PLACEMENT

The patient presented to the office on the day of surgery (Figure 3.45). Local anesthesia was administered throughout the maxillae. Periodontal probing/bone sounding was accomplished to refamiliarize the surgeon with the location of the alveolar crest around all of the maxillary teeth (Figure 3.46). The teeth were extracted with elevators and a full-thickness flap was reflected after extractions (Figures 3.47–3.49).

The surgical guide was placed onto the mandibular teeth, and the patient closed until the maxillary portion of the surgical guide touched the maxillary edentulous ridge (Figure 3.50). The alveolar ridge was adjusted for maximum, consistent contact with the intaglio surface of the surgical guide at the vertical dimension that was established on the articulator.



Figure 3.46. After local anesthesia was administered, a periodontal probe was used to identify the pocket depths and the levels of the crestal bone around each of the teeth. In this series of photographs, the surgeon was identifying the alveolar crest around the maxillary incisors.



Figure 3.47. Surgical image of the maxillary right central incisor being extracted with a surgical elevator.



Figure 3.50. The surgical guide was fitted to the incisal and occlusal surfaces of the mandibular teeth; the patient closed her mouth until the intaglio surface of the surgical guide contacted the maxillary edentulous ridge.



Figure 3.48. Surgical occlusal image of the maxillae immediately after all of the teeth were extracted.



Figure 3.51. The anterior wall of the maxillary sinus was identified and bone was removed to expose the maxillary sinus membrane.



Figure 3.49. A full-thickness flap was reflected after the teeth were extracted for the surgeon to visualize the anatomic contours of the alveolus.

The anterior portion of the right maxillary sinus was grossly identified and a #4 round bur was used to remove the bone, exposing the sinus membrane (Figure 3.51). A rounded probe was used to gently lift the membrane from the anterior wall of the maxillary sinus (Figure 3.52). The surgeon then palpated the anterior wall of the sinus and planned the angle of the osteotomy for the tilted, posterior implant. The orientation of the osteotomy was accomplished by scoring the bone on the lateral wall of the right maxilla, just anterior to the anterior wall (Figure 3.53). The implant was placed into the osteotomy, consistent with the orientation and location of the anterior wall of the sinus (Figures 3.54 and 3.55). The insertion torque was greater than 50Ncm. The implant was considered to have a good prognosis and was satisfactory for use in the IOL protocol.

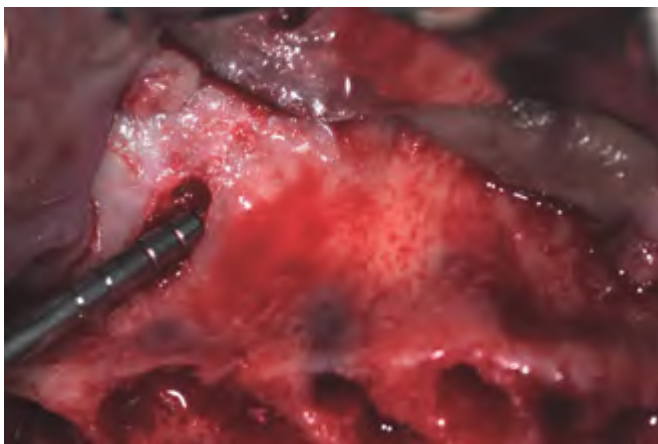


Figure 3.52. A rounded probe was used to gently lift the sinus membrane away from the floor and anterior walls of the maxillary sinus.

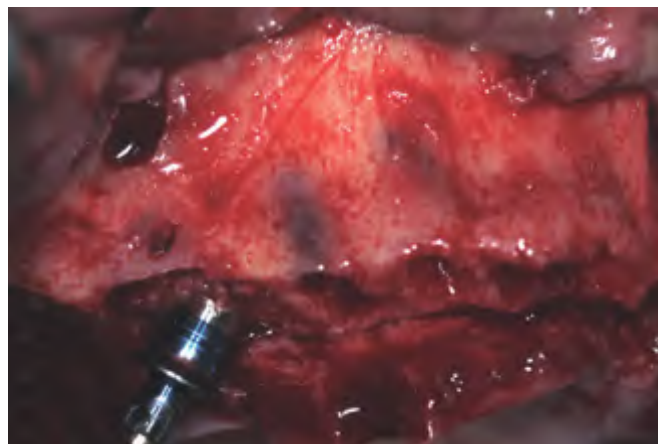


Figure 3.54. The right posterior tilted implant in place in the osteotomy parallel, but anterior, to the anterior wall of the maxillary sinus.

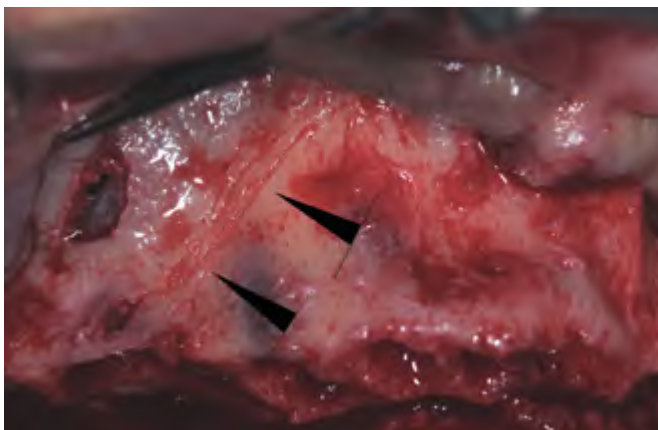


Figure 3.53. A line was scored into the lateral maxillary bone with a surgical curette, parallel to the anterior wall of the right maxillary sinus. The line can be seen just distal to the two arrows.

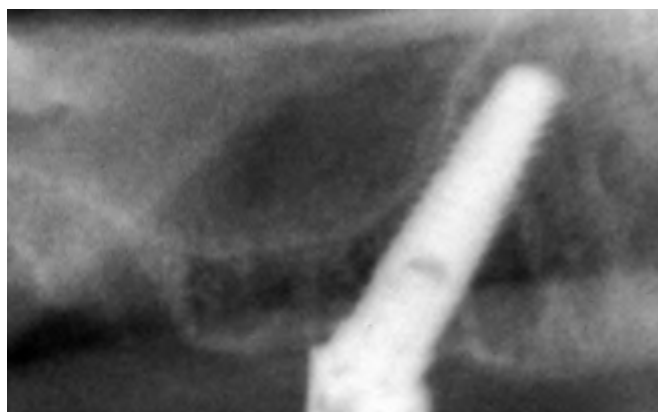


Figure 3.55. Radiograph after the right posterior tilted implant was placed. Note that the implant was parallel to the anterior wall of the maxillary sinus.

The anterior implants were placed into the appropriate vertical and mesial/distal positions by using the surgical guide (Figure 3.56). These positions were also consistent with the IOL protocol that was treatment planned (Figures 3.57 and 3.58). In this case, 4.1-mm-diameter external hex implants (Osseotite NT®, Biomet 3i, Palm Beach Gardens, FL) were used. All of the implants had insertion torques that exceeded 50Ncm.

ABUTMENT PLACEMENT

The prosthesis was designed to be screw retained to the abutments. There are multiple advantages to screw-retained prostheses, including:

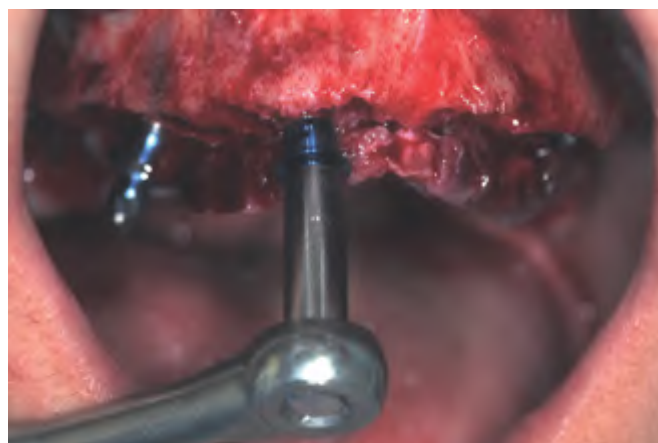


Figure 3.56. Surgical image of a hand ratchet driving the right anterior implant into place. The drilling unit was set to 50Ncm and was unable to deliver sufficient torque to the implant to place it into the correct position. The hand ratchet was required to optimally seat the implant into its correct position.



Figure 3.57. Surgical image of the surgical guide in place on the mandibular teeth. The implant restorative platform of the left anterior implant can be visualized in the area of the maxillary left lateral incisor of the surgical guide.



Figure 3.58. An occlusal view of the four maxillary implants in place. Note the significant anterior/posterior spread between the anterior and posterior implants. This spread was due, in part, to the tilted distal implants and allowed the patient to be restored with a full-arch prosthesis.

1. Retrievability
2. No cement that may be left behind and would act as irritant to the peri-implant soft tissues
3. Satisfactory retention

There are also disadvantages associated with screw-retained prostheses:

1. Screw loosening
2. Screw fracture
3. Prosthesis fracture
4. Incomplete seating/misfit of the prosthesis to the abutments



Figure 3.59. Conical abutments as received from the manufacturer. The two abutments on the left side were designed with 3- and 4-mm collar heights (SCA003 and SCA004, left to right, respectively). The two abutments on the right side of the image were designed with 17- and 25-degree angles and 4-mm collar heights (AC4417 and AC4425, left to right, respectively). All of the abutments were machined to fit the implant restorative platforms of 4.1-mm external hex implants.

Several factors can influence the stability of screw joints. Torque rotational forces on screws are measured in Newton centimeters (Ncm). Torque applied to screws affects the compressive forces in the threads of the screws and the compressive forces applied to the head of the screws in the recipient components. Torque also results in tensile forces within the screw itself. If the torque is too low, the clamping force holding the screw joint together will be low and may be inadequate to maintain the integrity of the screw joint. If the torque is too high, it may result in screw fracture or stripping of the threads. Preload is the initial load created by the application of torque to the screw joint and actually causes elongation of the screw in the joint (Haack and others 1995). Clamping forces are important criteria for clinically successful screw joints. Joint strength is increased with increased clamping forces.

Conical abutments were selected for use in this case because these abutments are ideally suited for full-arch screw-retained prostheses, are available in multiple collar heights, and with angle corrections of 17 and 25 degrees (Figure 3.59).

Due to the amount and shape of the remaining alveolar bone, all of the four implants were placed off-angle relative to the vertical plane. In order to locate the screw access openings within the occlusal and palatal surfaces of the maxillary prosthesis, angled conical abutments were selected. The orientations of the angled conical abutments were determined with the surgical guide in place (Figure 3.60). Seventeen-degree-angle conical abutments were selected for the anterior and posterior implants (AC4417, Biomet 3i) (Figures 3.61 and 3.62). Collar heights were chosen so that the ledges around the conical abut-



Figure 3.60. Abutments were selected and placed with the surgical guide in place to optimize their orientation. This allowed the screw access openings to be placed within the occlusal and palatal surfaces of the prosthesis.



Figure 3.62. Occlusal view of the 17-degree-angled abutment in place on the maxillary right anterior implant, consistent with the position of the maxillary right central incisor in the surgical guide. Note that the abutment was placed in such a way that the screw access opening for the prosthesis was completely confined within the palatal aspect of the prosthesis and would not be visible nor present an aesthetic compromise.



Figure 3.61. A contra-angle driver with a large hex tip (0.048 in.) was used to screw the abutment screw of the angled conical abutment into the maxillary left anterior implant.

ments would be located just inside the free gingival margins of the peri-implant soft tissues after the flaps were sutured. Four-millimeter collar heights were selected (Figure 3.63).

ABUTMENT IMPRESSION

Multiunit conical abutment impression copings (CSQ17, Biomet 3i) were used to record the intraoral positions of the abutments (Figure 3.64). A pick-up impression technique was utilized with a stock tray that was adjusted to fit around the clinical impression copings (Figure 3.65).



Figure 3.63. Clinical image with the implants and abutments in place, prior to flap closure. Once the orientation of the abutments was finalized, the abutment screws were torqued to 20 Ncm with a torque driver. Preangled conical abutment (17 degrees), AC4417 (inset).



Figure 3.64. Conical abutment multiunit pick-up impression copings were placed onto the conical abutments. CSQ17, multiunit impression coping (inset).



Figure 3.65. A stock plastic impression tray was adjusted to fit around the impression copings without interference from any of the impression copings or abutments.

Impression plaster was used as the impression material. Assif and others (1999) reported on a laboratory study where three implant impression techniques, using three different splinting materials, were assessed for accuracy in a laboratory model that simulated clinical practice. For group A, autopolymerizing acrylic resin was used to splint transfer impression copings. In group B, a dual-cure acrylic resin was used, and for group C, impression plaster, which was also the impression material, was used as the splinting material. An implant master framework was made to accurately fit a cast metal implant master cast. This cast was the standard for all of the impressions. For each group, 15 impressions were made. Polyether impression material was used for groups A and B. The accuracy of the stone casts with the implant analogs was measured against the master framework, using strain gauges. A multiple ANOVA with repeated measures was performed to test for significant differences among the three groups. Additional ANOVAs were carried out to locate the source of difference. The statistical analyses revealed that a significant difference existed between groups A and B (autopolymerizing and dual-cure resin splints) and between groups B and C (impression plaster) but not between groups A and C. Impression techniques using autopolymerizing acrylic resin or impression plaster as a splinting material were significantly more accurate than dual-cure acrylic resin. These authors concluded that impression plaster was the material of choice since it was easy to manipulate, was less time consuming, less expensive, and as or more accurate than the other impression protocols tested.

The definitive impression was made with impression plaster (ADA Type I, American Dental Association, Chicago, IL) (Figures 3.66–3.68; Table 3.2). The impression was disinfected and given to the dental laboratory



Figure 3.66. Impression plaster was used as the impression material. The impression coping screws were visible to ensure access to the screws for removal of the impression from the mouth.



Figure 3.67. A large hex driver was used to unscrew each of the impression coping screws prior to removal of the impression from the mouth.



Figure 3.68. The intaglio surface of the plaster pick-up impression. Note that all of the impression copings were completely surrounded and embedded into the impression plaster.

TABLE 3.2. Recommendations for Use and Physical Properties of Impression Plaster*

Liquid/powder ratio	100 cc/50 g
Set time	2–3 minutes
% setting expansion	0.13
Wet compressive strength	1.3 MPa
Dry compressive strength	5.9 MPa

Source: O'Brien (1989).

*Description: a fine-grind, high-purity plaster.

technicians for fabrication of the master cast and other laboratory procedures.

JAW RELATION RECORDS

Occlusal harmony and stability is essential for long-term clinical success in implant prosthodontics. With the full-arch prosthesis that was planned for this patient, the influence of the mandibular natural teeth and the forces associated with functional and parafunctional habits merited strong consideration in the treatment planning process. One of the goals of treatment included even occlusal contacts throughout the prosthesis with the patient in CO. Working side contacts were to include multiple teeth (group function), and there were to be no balancing contacts.

Since the maxillae were edentulous, jaw relation records needed to be made on the implant restorative components in the mouth and transferred to a semi-adjustable articulator. The interocclusal record was to be made with extra hard baseplate wax. The wax wafer would then be relined with Aluwax™ (Aluwax Dental Products Co., Allendale, MI). Aluwax dental wax is a composite material that contains powdered aluminum to increase the integrity of the compound and provides heat retention properties needed for efficient modeling. Wax interocclusal records are not as accurate as elastomeric interocclusal records, but in this case, the clinicians felt that the ease of use compensated for the lack of dimensional stability and accuracy (Ghazal and others 2008).

Healing caps were placed onto the conical abutments and hand tightened (Figure 3.69). Three layers of hard baseplate wax were fused together and cut into a shape that would impress the occlusal surfaces of the healing caps (Figure 3.70). The vertical dimension of occlusion measured at the beginning of the appointment was confirmed at the time the above record was made (Figure 3.71). The definitive CR record was made by relining the maxillary and mandibular surfaces of the wax wafer with Aluwax at the predetermined vertical dimension of occlusion (Figures



Figure 3.69. Healing caps (CS250, Biomet 3i) were placed onto the conical abutments and tightened by hand. The caps extended at least 2 mm supragingival and stabilized the record base during the jaw relation record. Healing cap as received from the manufacturer (inset).

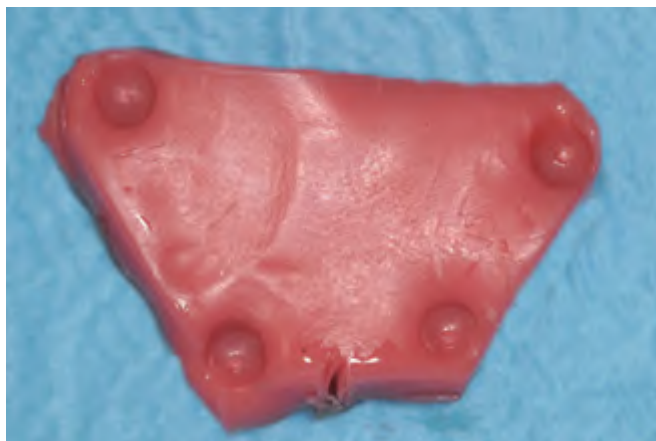


Figure 3.70. The maxillary occlusal surface of the wax wafer, with indentations of the four healing caps, recorded as the initial jaw relation record.



Figure 3.71. The vertical dimension of occlusion as recorded at the start of the surgical appointment. In this case, it measured 75 mm between the dots on the chin and the nose.



Figure 3.72. Intra- and extraoral views of the wax interocclusal record in place, at the preexisting vertical dimension of occlusion. The vertical dimension of occlusion was maintained with the use of the calipers that were used to record the preoperative vertical dimension of occlusion (left, inset).

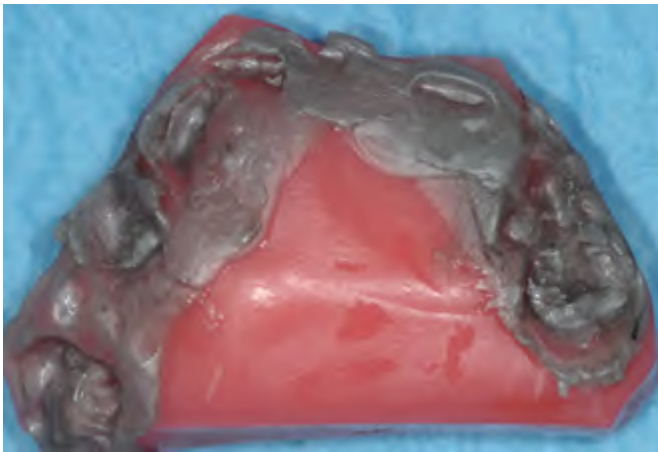


Figure 3.73. The mandibular occlusal surface of the wax wafer, relined with Aluwax, recorded with the definitive jaw relation record.

3.72 and 3.73). The facial midline was transferred to the wax interocclusal record (Figure 3.74).

The patient was discharged to return the next morning for insertion of the Columbus Bridge.

MASTER CAST

Laboratory analogs are replicas of the intraoral implant restorative components. In this case, they were made from stainless steel and were called conical abutment lab analogs (CLA20, Biomet 3i) (Figure 3.75). Since the impression was made with a pick-up impression technique, the abutment impression coping could not be removed from the impression. The dental laboratory technician seated the analogs correctly into the impression copings inside the impression (Figure 3.76).



Figure 3.74. The facial midline was transferred to the wax record. The occlusal surface of the wax record was made horizontal.



Figure 3.75. Conical abutment lab analog (CLA20).



Figure 3.76. Conical abutment lab analogs in place within a definitive abutment impression with pick-up impression copings.



Figure 3.77. Laboratory image of five laboratory analogs (inset) attached to five impression copings in place within an impression. A resilient acrylic resin material was injected to cover the impression coping/analog junctions. This material should be removable from the cast to allow complete access to the abutments for waxing, casting, and finishing the prosthesis.

Master casts for screw-retained prostheses present with different requirements than master casts for cement-retained implant prostheses. Space, up to 40 μ m, may be required for cement in cement-retained prostheses. Since all impression materials shrink with setting, stone expansion during fabrication of the master cast is required. Setting expansion of Type IV dental stones ranges from 0.01% to 0.1%, depending on the manufacturer (Kenyon and others 2005). Master casts for screw-retained prostheses must control for setting expansion because it may distort the interabutment distances (Wise 2001; Vigolo and others 2003).

In this case, after the abutment analogs were attached to the abutment impression copings within the impression, a resilient material was injected around the analog/impression coping junctions (Figure 3.77). Type IV dental stone was mixed as per the manufacturer's instructions and poured into the impression for fabrication of the master cast (Figures 3.78 and 3.79).

ARTICULATOR MOUNTING

Conical abutment healing caps were placed onto the abutment analogs within the master cast (Figure 3.80). This was required since the jaw relation record was made with healing caps in place. The jaw relation record was placed onto the conical abutment healing caps in the maxillary cast and the occlusal surfaces of the mandibular teeth in the mandibular cast. The casts were mounted using mounting stone, with the occlusal plane horizontal and in the center of the articulator (Table 3.3). The maxillary



Figure 3.78. Occlusal view of the master cast with the soft tissue replica of the peri-implant soft tissues in place. Conical abutment lab analog (CLA20; inset).



Figure 3.79. Occlusal view of the master cast with the soft tissue replica removed. This gave the dental laboratory technicians complete access to all of the conical abutment analogs.

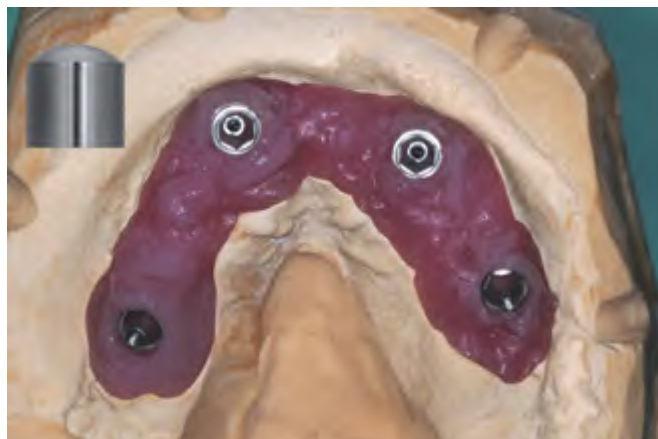


Figure 3.80. Healing caps (CS250; inset), consistent in size with the healing caps that were placed intraorally, were placed onto the abutment laboratory analogs in the master cast.

TABLE 3.3. Requirements of Mounting Stone*

Material should set quickly and hard	Working time: 2–3 minutes
Undergo minimal dimensional change	Setting time: 5 minutes
High strength	0.08%
	Wet: (1 hour) 4600 psi (32MPa)
	Dry: (48 hours) 8500 psi (59MPa)
Separate cleanly from the casts	
Permit reattachment after denture processing	

*Whip Mix Mounting Stone (Whip Mix Corporation, Louisville, KY).



Figure 3.81. Laboratory image of the right side of the articulator mounting.

midline was set consistent with the incisal guide pin (Figures 3.81 and 3.82). This articulator mounting was consistent with the original articulator mounting for the diagnostic setup and fabrication of the surgical guide. The articulator was an arcon type with a fixed intercondylar distance, an adjustable incisal guide table, and an adjustable incisal guide pin.

FABRICATION OF INTERIM SCREW-RETAINED IMPLANT PROSTHESIS

The denture teeth from the original setup were transferred to the new articulator mounting (Figure 3.83). Acrylic resin denture teeth were selected because they have:

1. Satisfactory, natural aesthetics
2. Adjustability



Figure 3.82. Laboratory image of the left side of the articulator mounting.

3. High strength
4. High bond strengths to processed acrylic resin

A silicone index was made of the denture setup, and the teeth were removed from the cast (Figures 3.84 and 3.85).

Construction of the Cast Metal Framework

Multiunit conical abutment gold cylinders (CAGC5, Biomet 3i) were placed onto the abutment analogs in the master cast (Figure 3.86). These cylinders are also available as castable cylinders. The clinicians chose the machined cylinders due to increased accuracy between the precision machined interfaces of the cylinders and the abutments after casting relative to the interfaces between cast components (Kano and others 2007).

The cylinders were luted together with autopolymerizing acrylic resin (GC Pattern Resin, GC America Inc., Alsip, IL) (Figures 3.87 and 3.88). Small beads were placed onto the resin framework to provide additional retention for the acrylic resin of the denture base. The precision of fit between the framework and the abutments is known to be affected by the characteristics of the pattern and the properties of the investment and casting process. In order to compensate for dental casting shrinkage, dental casting investments have been manufactured with known rates of expansion. Casting accuracy is dependent on the technique and skills of the dental laboratory technician; the size, shape, temperature and the type of casting ring; and the position of the pattern within the casting ring (Leal and others 2006) (Figure 3.89).

Metal shrinkage in dental castings has been a concern for dental laboratory technicians for many years. Metal shrink-



Figure 3.83. Laboratory images of the wax denture setup (middle: anterior centric occlusion; lower left: right posterior segments; lower right: left posterior segments).

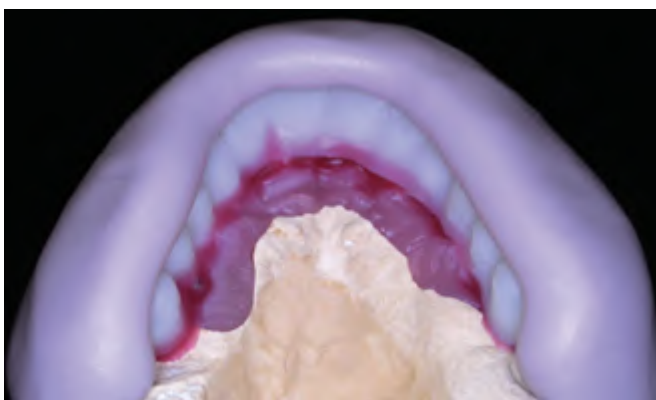


Figure 3.84. Laboratory palatal view of the silicone index in place on the master cast, prior to removal of the denture teeth. The index was keyed to notches on the land area of the master cast for accurate repositioning.



Figure 3.85. Close-up laboratory view of the silicone index in place on the maxillary right posterior segment. There was adequate space available for fabrication of the metal framework, denture teeth, and denture base.

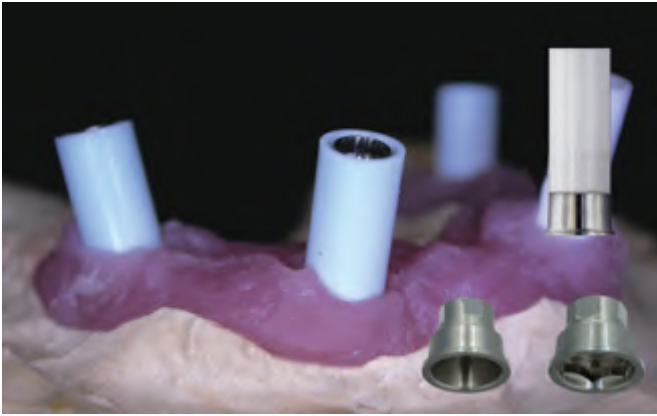


Figure 3.86. Laboratory lateral image of the conical abutment gold cylinders (CAGC5, as received from the manufacturer; upper inset) in place on the abutments in the master cast. The lower inset features the abutment restorative platforms for conical abutment gold cylinders (left, multiunit [CAGC5]; right, single unit [CNRG5]).

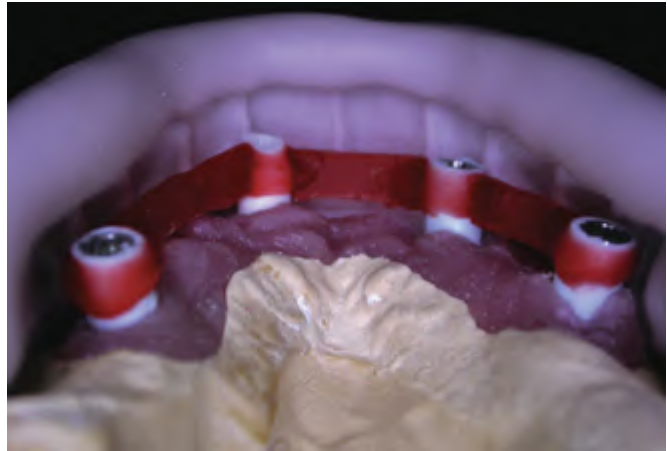


Figure 3.88. Care was taken to ensure that there was adequate space between the resin framework and the silicone index. This provides for adequate thickness for the resin/metal framework, the requisite strength for the framework, and adequate space for the denture base and denture teeth.

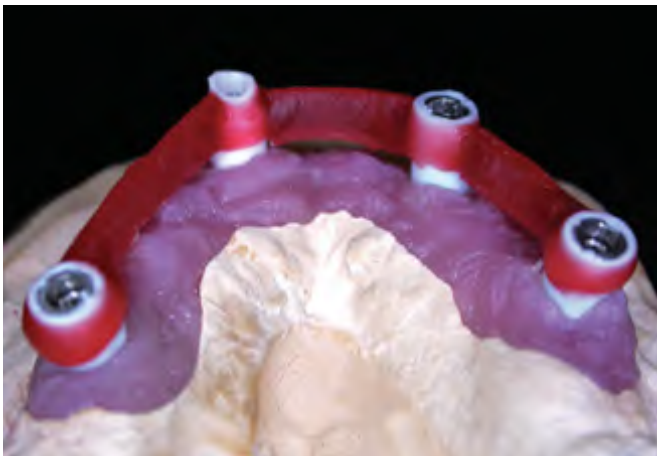


Figure 3.87. Laboratory palatal image of the gold cylinders luted together with autopolymerizing acrylic resin. The resin framework was made in sections, and each segment was allowed to polymerize for at least 10 minutes. The sections were then joined.

age varies with each metal alloy and manufacturer but is generally recognized to be in the range of 1.5% for high noble alloys and may approach 3% with low noble alloys (Gebelein and others 2003). The casting for this patient was made with a silver/palladium alloy and was cast in one piece. The advantages of casting the framework in one piece included time savings and maintenance of the work hardening properties associated with this particular alloy. The major disadvantage of making one-piece castings is the tendency for the castings not to fit passively on the analogs and/or implants (Carr and Brantley 1996).

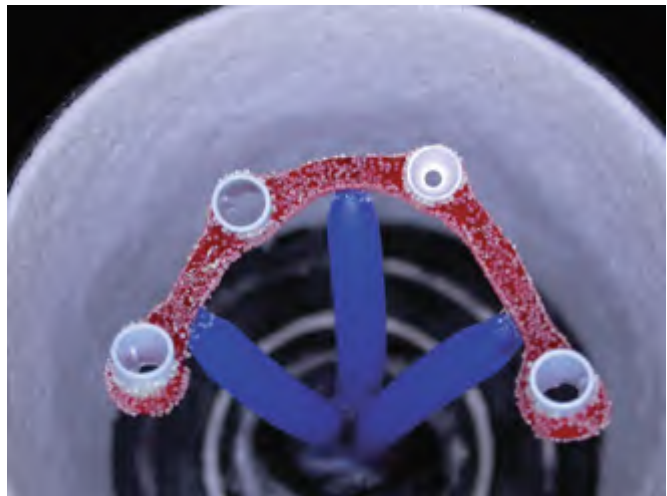


Figure 3.89. The resin pattern was sprued and placed into the investment ring.

Nonetheless, this framework was cast in one piece and fit the analogs accurately and passively (Figure 3.90).

Construction of the Hybrid Prosthesis

The framework was placed onto the master cast, and the master cast was remounted onto the articulator. Laboratory waxing screws (WSK10, Biomet 3i) were used to retain the framework to the conical abutment lab analogs (Figure 3.91). The silicone index was placed back onto the cast and the denture teeth were reset consistent with the



Figure 3.90. The framework was cast in one piece and was placed onto the master cast to evaluate the cylinder/abutment interfaces. Opaque acrylic resin was added to the framework to minimize metal show through of the denture base.



Figure 3.91. Laboratory waxing screw (WSK10). This screw was used to retain the framework to the analogs in the master cast during the laboratory procedures.



Figure 3.92. Illustration of a human skull with a complete dentition (left). Illustration of the same skull with edentulous jaws (right). Note how the edentulous maxillae resorb vertically and posteriorly and the edentulous mandible resorbs anteriorly and inferiorly. Optimal positioning of the denture teeth will compensate for these resorptive changes.

original wax set. Anteroposterior positioning of the anterior teeth is extremely important in development of optimal aesthetics and phonetics because of the support that natural or artificial teeth provide to the lips and cheeks. Since optimal support of these tissues is essential for aes-

thetics and phonetics, it is important to place the artificial teeth in essentially the same position as the natural teeth (Figure 3.92). Patients undergo residual ridge resorption after the loss of the natural teeth (Tallgren 1972). Residual ridge resorption can be minimized with the protocol that



Figure 3.93. Clinical occlusal image of the edentulous maxillae immediately after the teeth were extracted. This arch form was classified as square tapering.



Figure 3.94. Anterior laboratory view of the denture teeth in place on the cast metal framework.

was used for this patient: extraction and immediate implant placement.

This patient's arch form was considered to be square tapering (Figure 3.93). As such, denture tooth arrangement combines parts of the protocols for square and tapering arch forms:

1. Square placement of the central incisors
2. Slight rotation of the lateral incisors and cuspids
3. Cuspids often show more distal rotation than in a typical square arch form

The central incisors were set at an inclination slightly distal to the vertical plane, with the incisal edges on the occlusal plane. The lateral incisors were also set with a distal tilt and twisted to show more of the mesiolabial line angles. The cuspids were set vertically, as per the patient's request (Figure 3.94).



Figure 3.95. Right laboratory posterior view of the denture teeth on the framework. The denture teeth were set for maximal intercuspation against the mandibular natural teeth. The setup was not perfect, given the atypical orientations of the mandibular natural teeth.



Figure 3.96. Left laboratory posterior view of the denture teeth on the framework. The denture teeth were set for maximal intercuspation against the mandibular natural teeth. The setup was not perfect, given the atypical orientations of the mandibular natural teeth.

The maxillary posterior teeth were replaced with 20-degree, acrylic resin denture teeth. The posterior teeth were set in maximum intercuspation with the mandibular natural teeth. Right and left working occlusions were designed for group function. The patient did not receive a full complement of maxillary teeth secondary to the location of the four implants supporting the prosthesis (Figures 3.95 and 3.96).

The denture teeth were processed onto the metal framework with heat-cured, tooth-colored acrylic resin. The pontic surfaces of the prosthesis were contoured to be convex consistent with ovoid pontics (Figures 3.97–3.99). All polishing procedures were accomplished with polishing protectors in place (PPCA3, Biomet 3i).



Figure 3.97. Right laboratory posterior view of the processed prosthesis. The soft tissue replica was removed. The prosthesis was polished with polishing protectors (PPCA3) in place, retained by laboratory screws (WSK10). Polishing protector for a conical abutment (inset).



Figure 3.98. Left laboratory posterior view of the processed prosthesis. The soft tissue replica was removed. The prosthesis was always polished with polishing protectors (PPCA3) in place, retained by laboratory screws (WSK10). Polishing protector for a conical abutment (inset).

INSERTION

The patient returned the next morning for insertion of the prosthesis. She reported that she spent a comfortable night and was anxious to get her prosthesis (Figure 3.100). The healing caps were removed without incident or discomfort, and the angled conical abutments were visualized (Figures 3.101 and 3.102).

The prosthesis went to place with one retaining screw placed into the right distal screw access opening (Gold-Tite® Retaining Screw, GSH30, Biomet 3i). The screw was placed with a 0.048-in. large hex driver (PHD03, Biomet 3i), and a periapical radiograph was taken of the left distal abutment/cylinder interface (Figure 3.103). Since there



Figure 3.99. Laboratory occlusal view of the definitive prosthesis after polishing. The clinical retaining screws are also evident (GSH30). Clinical gold-coated screws should not be used in any dental laboratory procedures.



Figure 3.100. This is an intraoral image of the patient when she returned the day after surgery. The healing caps were visible and the implants were stable. There was no active bleeding; she had mild swelling intra- and extraorally.

were no gaps visible between the framework and the left distal abutment/cylinder interface, the prosthesis was judged to pass the one-screw test for passive fit. The process was repeated on the other side of the prosthesis with similar results (Figure 3.104).

The pontic surfaces of the prosthesis were adjusted to minimize the pressure placed on the peri-implant soft tissues. The retaining screws went to place with 10Ncm of torque, and the screw access openings were partially blocked out with cotton and restored with light-cured composite resin (Figures 3.105–3.108). The occlusion was adjusted to achieve even occlusal contacts



Figure 3.101. This intraoral image was taken immediately after the healing caps were removed. The conical abutments were visible. The implants were stable; the patient was comfortable.



Figure 3.102. Intraoral occlusal view of the maxillary implants and conical abutments after the healing caps were removed.

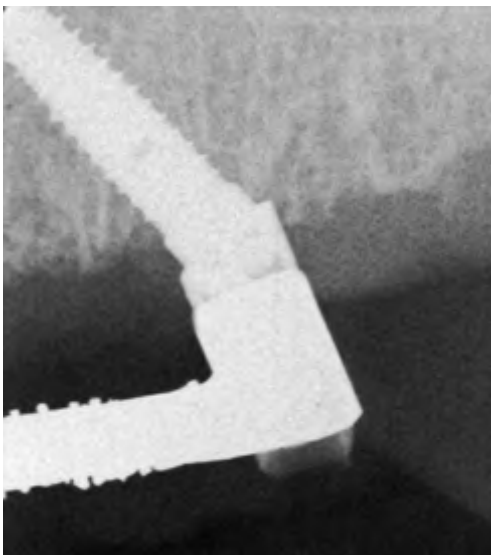


Figure 3.103. Periapical radiograph of the left distal implant/abutment/cylinder interface that demonstrated an accurate fit between the implant components. There was a retaining screw in the right distal portion of the prosthesis (not pictured). Per the Columbus Bridge Protocol, the framework was not cantilevered distal to the last implant.

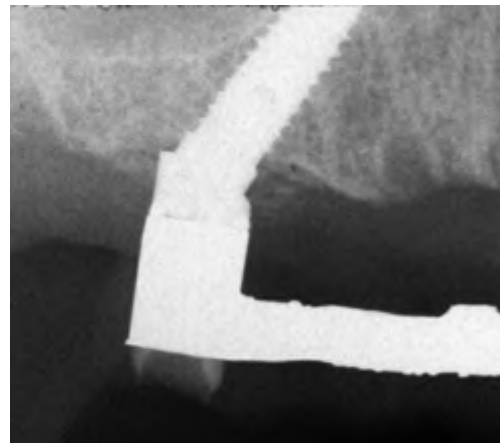


Figure 3.104. Periapical radiograph of the right distal implant/abutment/cylinder interface that demonstrated an accurate fit between the implant components. There was a retaining screw in the left distal portion of the prosthesis. Per the Columbus Bridge Protocol, the framework was not cantilevered distal to the last implant.



Figure 3.105. Maxillary occlusal image of the prosthesis in place. The retaining screws (GSH30) were tightened to 10 Ncm of torque.



Figure 3.106. Intraoral anterior clinical image of the patient with the prosthesis in place, in centric occlusion. This photograph was taken the day after the extractions and implant placement. Even occlusal contacts were developed throughout the prosthesis.



Figure 3.108. Left intraoral clinical image of the patient with the prosthesis in place, in centric occlusion. This photograph was taken the day after the extractions and implant placement. Even occlusal contacts were evident developed throughout the prosthesis.



Figure 3.107. Right intraoral clinical image of the patient with the prosthesis in place, in centric occlusion. This photograph was taken the day after the extractions and implants and implant placement. Even occlusal contacts were developed throughout the prosthesis.



Figure 3.109. Clinical images that illustrate even occlusal contacts that existed between the maxillary implant-retained prosthesis and the mandibular natural teeth.

throughout the prosthesis (Figure 3.109). The patient was given postoperative instructions and was scheduled to return in 1 week for removal of the prosthesis, suture removal, and further adjustments as needed. She was extremely pleased with the aesthetic results (Figures 3.110 and 3.111).

ONE-WEEK POST-INSERTION CLINICAL VISIT

The patient returned 1 week later and reported that she was extremely pleased with the aesthetic, functional, and phonetic results (Figure 3.112).



Figure 3.110. Clinical image of the patient smiling just prior to discharge from the dental office.



Figure 3.111. Clinical image of the patient, in profile, smiling just prior to discharge from the dental office.



Figure 3.112. Clinical image of the patient smiling 1 week after the surgical and prosthetic appointments. There was no evidence of perioral swelling or bruising.

The composite resin and cotton were removed from the screw access openings, and the screw heads were identified. The retaining screws were removed with the 0.048-in. large hex driver without incident. The prosthesis was removed (Figures 3.113 and 3.114). The soft tissues were healing nicely, with minimal swelling, no bleeding, and no signs of infection. There were no signs of overextension or excessive pressure between the prosthesis and the soft tissues. The sutures were removed, and the prosthesis was reconnected with the original retaining screws. The screws were tightened to 10Ncm without incident, and the screw access openings were blocked out with cotton and restored with light-cured composite resin.

The patient was discharged and asked to return in 3 months, unless there were problems. This patient is now



Figure 3.113. One-week postoperative clinical anterior image after the screw-retained maxillary prosthesis had been removed. There was excellent soft tissue healing with no sign of infection or other problems.



Figure 3.114. One-week postoperative clinical maxillary occlusal image after the screw-retained maxillary prosthesis had been removed. There were no clinical signs of an adverse response.

approximately 18 months post insertion and doing extremely well. Her next scheduled visit will be in 6 months (24 months postoperative) for clinical and radiographic follow-up.

The following clinicians and dental laboratory technicians were responsible for the treatments illustrated in this chapter:

Clinicians: Tiziano Tealdo, DDS, MD; Marco Bevilacqua, DDS; and Paolo Pera, MD, DDS, Department of Prosthetic Dentistry, University of Genoa, Genoa, Italy

Dental Laboratory Technicians: Luca Scaglione, Piercarlo Seghesio, and Santo Stefano, Belbo, Italy

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Chapter 4: Robot Analog Placement and CAD/CAM Abutments

INTRODUCTION

The fit between implant restorative components and implants has been reported to be an important factor in the overall longevity of successful implant restorations (Binon 1995, 1996; Jemt and Book 1996; May and others 1997; Byrne and others 1998). Misfits between implants and implant restorative components can generate significant stresses within the implant/abutment/restorative complex and result in screw loosening, screw fracture, loss of restorations, and potentially, loss of implants (Skalak 1983) (Figure 4.1).

Restorative dentists and dental laboratory technicians strive to fabricate precisely fitting implant restorations that include stable screw joints, especially with screw-retained fixed prostheses. Binon reported that implants and implant restorative components should have minimal rotation (less than 2 degrees) and that this would decrease the likelihood of screw loosening (Binon 1996). There have been numerous reports of screw loosening in implant screw-retained prostheses. In one study (Becker and Becker 1995), the authors reported a high cumulative survival rate (CSR) for molar implants (95%). All of the restorations were single units, made on nonrotating gold cylinders. The occlusion was developed to minimize centric contacts and lateral interferences. Becker and Becker (1995) reported that the gold retaining screws loosened in eight implant restorations between one and three times (38%). The authors concluded that single-molar implants were biologically predictable; however, clinicians should expect a high incidence of screw loosening. With increased precision in manufacturing and a better understanding of torque and preload, the incidence of screw loosening has decreased (Norton 2001) (Figure 4.2).

Laboratory processing (casting, investing, wax burnout, divesting, etc.) of implant-retained restorations may alter the surfaces of the abutments in contact with the implant restorative platforms and thus negatively impact the implant/abutment interface (Figure 4.3). Vigolo and others (2000) assessed the changes at the implant interface of single-unit, gold-machined UCLA abutments after casting and porcelain applications. They reported no significant differences relative to the study parameters (depth of the external hex, width of the hex, apical diameter of the

abutments, and the degrees of rotation between the abutments and implants) were observed during laboratory processing of the restorations ($P = 0.576$). Vigolo and others (2000) concluded that if all laboratory steps are observed carefully, changes at the implant interface of gold-machined UCLA abutments would not occur.

Vigolo and others (2008) also studied the precision at the implant/abutment interface of gold-machined UCLA-type abutments and computer-aided design/computer-aided manufacturing (CAD/CAM) titanium abutments with both external-hexagonal and internal-hexagonal connections (Figure 4.4). They concluded that both types of abutments (gold-machined UCLA-type and CAD/CAM titanium) consistently showed 1 degree of rotational freedom at the implant/abutment connection for both external-hexagonal and internal-hexagonal connections. However, other authors have found issues with finishing cast UCLA abutments.

CAD/CAM has been adapted from industry to dentistry in terms of fabricating implant abutments, implants, crowns, and implant-supported frameworks. CAD/CAM abutments present numerous advantages over cast abutments:

1. Precision milling from solid blanks of titanium, titanium alloy, or ceramic
2. Elimination of the problems inherent to the casting process: porosity, miscasts, inaccuracies in the implant/abutment interface
3. Decreased labor and costs

Beier and others (2007) evaluated the clinical success of a hydrophilic polyvinyl siloxane impression material for fixed dental restorations under various clinical conditions. A total of 1466 preparations for fixed restorations in maxillary and mandibular anterior and posterior teeth were evaluated. The study contained inlay, onlay, crown, veneer, post, and adhesive preparations, as well as impressions for implant restorations. The preparation finish line relative to the crest of the marginal gingiva, type of restoration, and position of the teeth and implants were recorded. Three categories were established to rate impression quality: perfect impressions, no voids or bubbles, and perfect reproduction of the preparation finish line, were rated



Figure 4.1. Laboratory image of the occlusal third of a fractured implant (left) and a standard abutment and screw (right). The patient presented with these components in her hand after noticing that the abutment was loose for “a while.”



Figure 4.2. Clinical occlusal image of the implant restorative platform of an external hex implant in a mandibular second molar site. The patient noticed that the abutment was loose for several weeks before coming in for evaluation. The sharp corners originally present in the external hex have been rounded due to rotation of the abutment on the implant hex, secondary to the loose abutment screw.

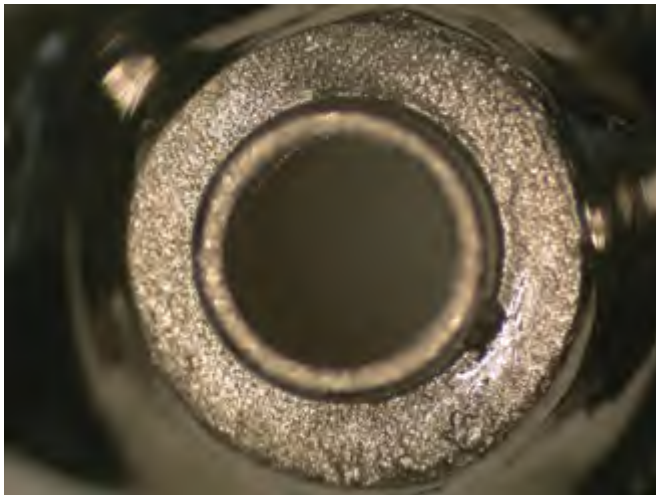


Figure 4.3. Laboratory image of the restorative platform of a cast UCLA nonhexed abutment (15× magnification). Even though polishing protectors were used, the machined interface has been damaged during the casting and finishing process. This may have a negative impact on the implant/abutment connection and long-term stability of the abutment and restoration.

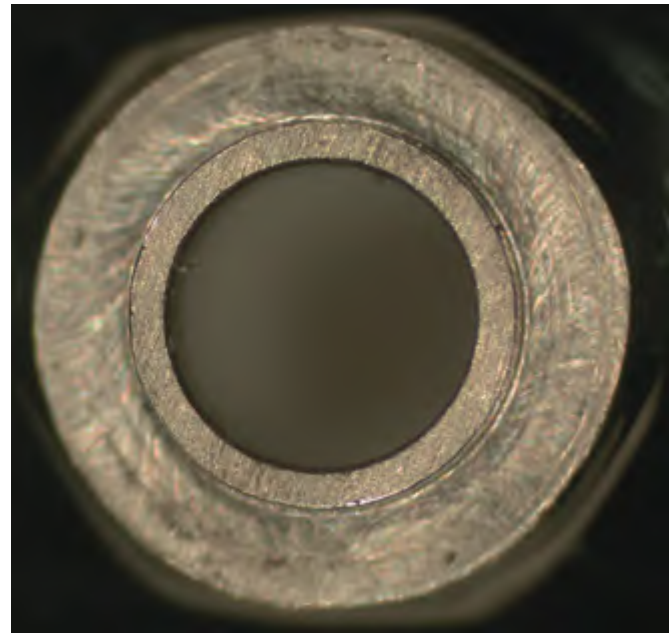


Figure 4.4. Laboratory image of the restorative platform of a CAD/CAM nonhexed abutment (15× magnification). The machined interface was not damaged during the milling and finishing process and should not have a negative impact on the implant/abutment connection and long-term stability of the abutment and restoration.

Criteria I; acceptable impressions, with minimal defects ($\leq 2\text{mm}$) not involving the preparation finish line, were rated Criteria II; and unacceptable impressions, with larger voids or bubbles ($> 2\text{mm}$) or defects involving the preparation finish line, were rated Criteria III. Overall, 96.86% of the definitive impressions were clinically acceptable: 89.43% were rated Criteria I, and 7.43% were rated Criteria II. Only 3.14% of the impressions were unacceptable and rated Criteria III. A significant influence on impression quality was found when the preparation finish line was placed more than 2mm subgingival ($P < 0.004$), as well as when a beveled preparation was used ($P < 0.004$). The position of the teeth ($P > 0.404$) had no significant effect on the accuracy of the impression process. Beier and others (2007) concluded that surface-activated polyvinyl siloxane impression material offered high predictability to avoid bubbles and voids in definitive, clinical impressions.

Implant-level impressions have also proven to be challenging to the dental profession. Wostmann and others (2008) analyzed the influence of impression technique (pick-up versus transfer) and material on the accuracy of working casts in implant restorative dentistry. Sixty impressions were made with three materials from a master cast with four implants (XiVE®, Dentsply Friadent, Friadent GmbH, Mannheim, Germany). The changes in the implant axis direction, rotation, and three-dimensional (3-D) shifts were assessed. The pick-up technique showed significantly ($P < 0.05$) lower values for axis direction and 3-D shifts but higher values for rotation than did the transfer technique. The differences between impression materials were not significant ($P > 0.05$, *H*-test). They concluded that the impression technique, not the impression material, had a significant influence on the accuracy of implant master casts.

Vigolo and others (2005) evaluated the accuracy of master casts obtained by using (1) copings modified by sandblasting and coating their roughened surfaces with impression adhesive before definitive impression procedures; and (2) gold-machined UCLA abutments as impression copings in definitive impression procedures for single-tooth implant restorations. A polymeric resin model with a standard single implant was used to simulate a clinical situation. A group of 20 impressions were made using square impression copings sandblasted to roughen their external surfaces at a supragingival level and then coated with polyether impression adhesive; a second group of 20 impressions were made using gold-machined UCLA abutments as impression copings. The castable parts of the UCLA abutments were secured with autopolymerizing acrylic resin to the gold-machined sections of the UCLA abutments to prevent movement of the castable parts on the gold-machined portions during the impression procedures; the castable portion of the UCLA abutment was also

coated with polyether adhesive to improve the stability of the gold-machined UCLA abutment inside the impression material. Master casts fabricated for both groups were analyzed to detect rotational positional changes of the hexagon on the implant replicas in the master casts, with reference to the resin model. The authors reported that the rotational positional changes of the hexagons on implant replicas were significantly less variable in the master casts obtained using gold-machined UCLA abutments as impression copings than in the master casts achieved with the roughened square impression copings. Vigolo and others (2005) concluded that using gold-machined UCLA abutments as impression copings in the final impression procedures should enable clinicians to achieve a more accurate orientation of the implant replicas in the laboratory master casts for single-tooth implant replacement.

Priest (2005) published a paper on CAD/CAM abutments and stated that computer-designed and computer-machined implant abutments will fundamentally change the present restorative protocols for implant dentistry. Standard implant prosthetic techniques rely on implant-level impressions and costly casting technology for component fabrication. Priest (2005) stated that many dentists are uncomfortable making implant-level impressions and resort to time-consuming conventional techniques of intraoral abutment preparation or do not offer dental implants as treatment alternatives to their patients. Implant abutments generated by CAD/CAM are more precise than those created using traditional casting technology. This increased accuracy has specific application to implant dentistry, where precision of components may affect implant longevity, prosthetic success, and ease of restoration.

Priest (2005) reviewed three current CAD/CAM implant abutment systems, including a digital system that eliminated the need to make implant-level impressions. After placing encoded healing abutments onto implants by either the implant surgeon or restorative dentist, an impression can be made of this specific healing abutment. A cast is poured in conventional fashion, and the resulting cast is then optically scanned. Using a CAD/CAM system and specific computer software, a patient-specific definitive abutment is created. The abutment is then milled and returned to the dental laboratory for fabrication of the definitive implant crown restoration. The encoded healing abutment is not removed from the implant until delivery of the abutment and definitive crown. The ease and precision of making implant impressions at the healing abutment level followed by patient-specific computer-generated abutments present several benefits to the implant team: restorative dentists rely less on conventional dental techniques to restore implants, the clinical time required for impression is less, and the known inaccuracies of casting

technology are virtually eliminated. Dental laboratory technicians are allowed to concentrate on higher-level activities such as custom application of ceramics to copings and custom staining. Dental laboratory technicians no longer have to spend untold man-hours waxing, casting, and finishing single-unit casting. Ultimately, dentists may be more likely to embrace implants as a preferred treatment option for their patients.

Priest (2005) predicted that this cutting-edge technology of computer-assisted implant impressions and computer-generated abutments will likely replace traditional implant restorative protocols and become the standard for implant dentistry in the foreseeable future.

THE ENCODE COMPLETE RESTORATIVE SYSTEM

Since 2004, it has been possible to fabricate custom milled titanium abutments, Patient Specific Restorations®, using the Encode® Restorative System (Biomet 3i, Palm Beach Gardens, FL). With this system, surgeons place special healing abutments (Encode® Healing Abutments [EHAs]) that have been manufactured with computer codes embedded into their occlusal surfaces (Figure 4.5). These healing abutments may be placed at the time of implant placement or at the time the implants were uncovered with a two-stage surgical protocol. EHAs have been designed as two-piece healing abutments (Figure 4.6) and are available in multiple collar heights (3, 4, 6, and 8 mm) (Figure 4.7). They are available for 3.4-, 4.1-, 5-, and 6-mm implant restorative platforms.

The Encode® Complete Restorative System (Biomet 3i) eliminates the need for implant-level impressions while delivering custom milled titanium abutments with appropriate gingival margin heights relative to the peri-implant soft

tissues and natural emergence contours for a given implant restoration. Definitive, custom CAD/CAM abutments are designed and milled from an impression of the EHA in place intraorally (Figure 4.8). Codes embedded onto the occlusal surface of the EHA communicate the collar height, implant hex orientation, platform diameter, and implant interface (the Certain® Internal Connection or External Hex Connection, Biomet 3i).

Once the surgeon places EHAs at the time of implant placement or at implant uncovering, and the soft tissues



Figure 4.6. Profile view of the abutment screw going into an Encode Healing Abutment (IEHA454). This healing abutment was designed with a 4-mm implant restorative platform (blue) and a 5-mm emergence profile. In order for this system to function as designed, the healing abutment must be correctly seated onto the hex of the implant restorative platform.



Figure 4.5. Occlusal view of Encode Healing Abutments (5-, 6-, and 7.5-mm emergence profiles, left to right). The occlusal codes can be read by a scanner/computer and identify the orientation of the hex, the size of the implant restorative platform, and the implant/abutment interface. IEHA554, IEHA564, and IEHA574 (Biomet 3i; left to right).



Figure 4.7. Profile view of Encode Healing Abutments (5-, 6-, and 7.5-mm emergence profiles, left to right). These healing abutments were designed with 5-mm implant restorative platforms. All had 4-mm collar heights. IEHA554, IEHA564, and IEHA574 (Biomet 3i; left to right).

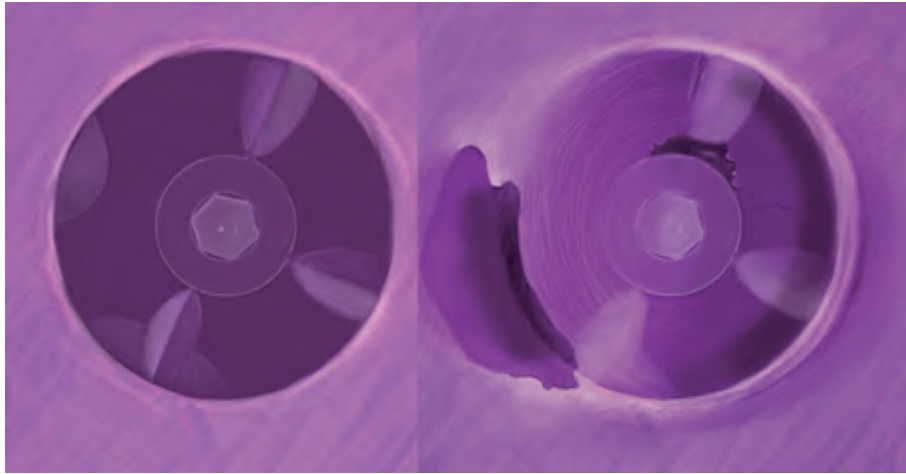


Figure 4.8. Illustrations of a satisfactory impression of an Encode Healing Abutment (left); unsatisfactory impression of an Encode Healing Abutment (right).



Figure 4.9. Clinical occlusal view of an Encode Healing Abutment in place in a maxillary right lateral incisor space. The entire occlusal surface of the healing abutment was supragingival, and all of the computer codes were visible.

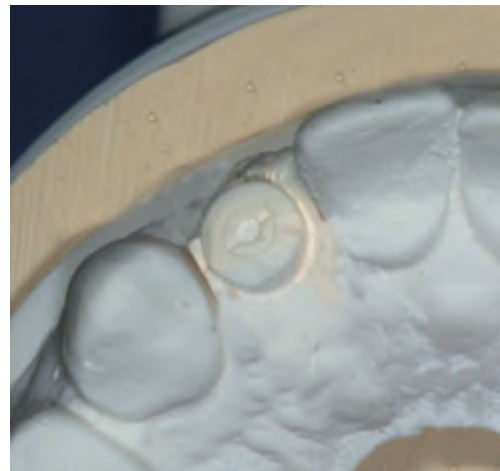


Figure 4.10. Laboratory occlusal view of the master cast with the die of the Encode Healing Abutment. The scanner will image the die and then a computer program will process the digital information of the codes. This will identify the type of the implant/abutment connection, the orientation of the implant hex, the collar height, and the size of the implant restorative platform. The soft tissue margins will also be recorded in anticipation of the design of the definitive abutment.

have matured, the Encode Complete Restorative System eliminates the need for implant-level impressions. The restorative dentist does not need to disturb soft tissue healing by removing and replacing the healing abutment or by using traditional implant impression copings. The restorative dentist needs only to make a crown and bridge type of impression of the EHA. The occlusal surface of an EHA has to be at least 1mm supragingival around the entire circumference of the abutment so as to completely expose the codes on the occlusal and axial surfaces

of the EHAs (Figure 4.9). The definitive impression of the EHA, the opposing cast, the interocclusal record (if needed), and the shade for the definitive crown is sent to a commercial dental laboratory for processing. Die stone is mixed per the manufacturer's instructions, and a master cast is poured in conventional fashion (Figure 4.10). It is essential not to pin the master cast as in conventional fixed prosthodontics because a robot will remove the stone in the area of the EHA in die stone (Figure 4.11).



Figure 4.11. Laboratory image of the underside of a cast, received at the PSR Department, Biomet 3i. This cast was pinned as in conventional fixed prosthodontics. The pins made this cast unacceptable for use with the Encode Complete Restorative System and robotic lab analog placement. The case was returned to the commercial dental laboratory for construction of a new cast.



Figure 4.13. Illustration of casts that were incorrectly mounted relative to the Encode Complete Restorative System protocol: the occlusal plane was not centered vertically between the upper and lower members, and the casts were mounted significantly anterior to the mounting plates.



Figure 4.12. Laboratory image of casts correctly mounted in a system-compatible articulator. Note that the casts were mounted directly in line (vertically) with the mounting plates; the occlusal plane was centered vertically within the articulator.

The casts must be mounted in a system-compatible articulator with Adesso magnetic mounting plates (Figure 4.12) (Stratos™ 100, Ivoclar Vivadent, Amherst, NY). The casts must be mounted directly (vertically) in line with the mounting plates; the occlusal table must be centered vertically between the upper and lower members and the incisal guide pin must be set at zero (Figure 4.13). A common articulator mounting error that has been reported occurs when, prior to mounting the casts, the incisal guide pin has not been zeroed at the commercial dental laboratory. Incorrectly mounted casts will have a major impact on scanning and the virtual articulator mounting in the computer (Figures 4.14 and 4.15). The laboratory technician completes the work order (Figure 4.16) and sends the mounted casts to Biomet 3i's Architech PSR® Department.

The cast with the EHA (in stone) is scanned. The scanner interprets the codes and records the dental and gingival architectures. The digital data are sent to PSR designers for design of the definitive Encode Abutment, as well as to the laboratory for fabrication of the Robocast™ (Biomet 3i). Robocast technology involves removal of the stone in the area of the planned implant analog and placement of the appropriate implant lab analog into the cast by virtue of



Figure 4.14. These casts were placed onto the verification articulator at the PSR Department, where this articulator is calibrated every day. This articulator mounting was not accurate as the premolars were not in occlusal contact. The case was returned to the commercial dental laboratory for remounting.



Figure 4.15. This is an image of an incisal guide pin (on the calibrated articulator in the PSR Department) that was not contacting the incisal guide table by 4.17 mm. Note the pad of paper that was placed between the incisal guide pin and the incisal guide table to indicate the amount of error. The original mounting was not accurate. The casts were returned for remounting.

the digital data obtained from the scan of the EHA cast. The original die stone cast is placed into the robot mount, using the original articulator mounting plate. The robot removes the stone in the indicated area. The implant lab analog is positioned, oriented, and secured into the cast and replicates the implant position in the patient. This results in the fabrication of a Robocast, which the commercial dental laboratory uses to fabricate the definitive restoration (Figures 4.17–4.23).

At the same time that the Robocast is being made, the Encode Abutment is being designed (Figure 4.24). A CAD healing abutment master drawing is aligned over the healing abutment scan data for abutment design and placement accuracy. Implant depth, interface, hex orientation, and platform diameter are captured relative to the interproximal and opposing dentitions, emergence profile requirements and gingival margins. In proprietary CAD software, the PSR technicians design the patient-specific definitive abutment with appropriate margin height and natural emergence contours according to the laboratory and clinician specifications. The virtual abutment design data are sent to the CAM Center and milled from a titanium alloy blank. All of the blanks have premachined interfaces for optimal implant/abutment fit and are used to mill the definitive Encode Abutments. After it has been milled, the Encode Abutment is placed onto the master cast, and the case is returned to the commercial dental laboratory for fabrication of the crown restoration (Figure 4.25).

CLINICAL PATIENT PRESENTATION

A 52-year-old male patient presented to the periodontist's office with a chief complaint that included acute pain upon chewing in his mandibular right posterior quadrant (Figure 4.26). The tooth was considered nonrestorable and was extracted (Figures 4.27 and 4.28). Bone grafting was accomplished at the time of extraction, and the site was allowed to heal (Figures 4.29 and 4.30).

DIAGNOSIS

The following diagnoses were made:

1. Excellent osseous healing in the right mandibular first molar site
2. Adequate bone volume for placement of a 5-mm-diameter implant
3. Adequate restorative volume for restoration of the implant with a molar-sized crown
4. Adequate band of fixed keratinized tissue for an implant restoration



Figure 4.17. This robot removes the stone from the master cast in the implant site and places the laboratory analog into its correct 3-D position.



Figure 4.18. Laboratory occlusal image of a cast, poured in die stone. The Encode Healing Abutment was reproduced in stone. Note that the codes are clearly visible and the entire occlusal surface of the healing abutment is at least 1 mm supragingival.



Figure 4.19. Laboratory image of the robot with a drill bit in place, in the process of removing the stone from master cast. The stone will be specifically removed in the area of the Encode Healing Abutment.

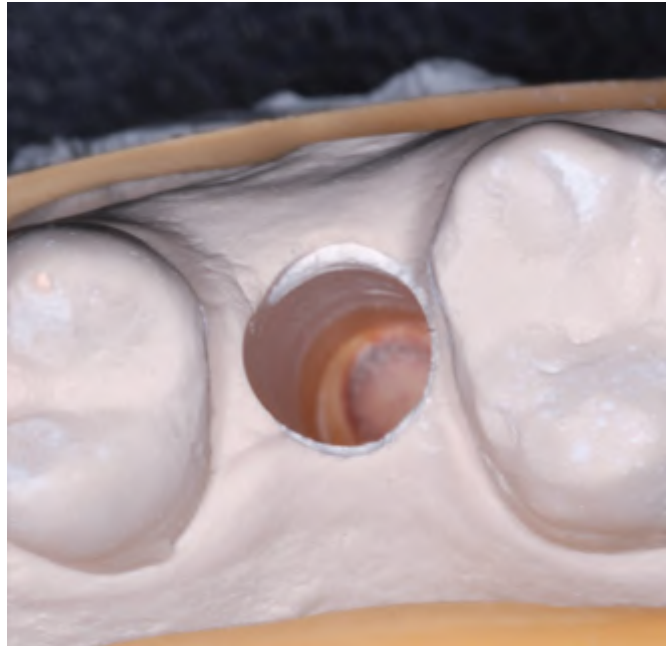


Figure 4.20. Laboratory occlusal image of the hole in the cast, drilled by the robot.



Figure 4.21. Laboratory image of a 4-mm-diameter implant laboratory analog attached to the holder in the robotic arm.



Figure 4.22. Laboratory image of the 4-mm implant laboratory analog, in its correct 3-D position. The analog was held in place by the robotic arm. The analog was secured into place with cyanoacrylate cement. The remnants of the cement activator can be seen on the stone cast.



Figure 4.23. Laboratory occlusal image of the implant lab analog in its correct 3-D position, in the master cast. Note the lack of any type of emergence profile or soft tissue replica in the cast. The emergence profile of the definitive Encode Abutment was already designed, consistent with the digital information obtained from the codes of the scanned Encode Healing Abutment.



Figure 4.24. Five Encode Abutments. Note that the emergence profiles of the abutments are independent of any of the peri-implant soft tissue contours because they were established from the contours of the scanned casts.



Figure 4.25. Laboratory image of the five Encode Abutments milled from the designs in Figure 4.24. The emergence profiles and gingival margins were milled into the abutments from the data of the scans. The ceramist will make the restorations fit the emergence profiles and gingival margins of the machined abutments.

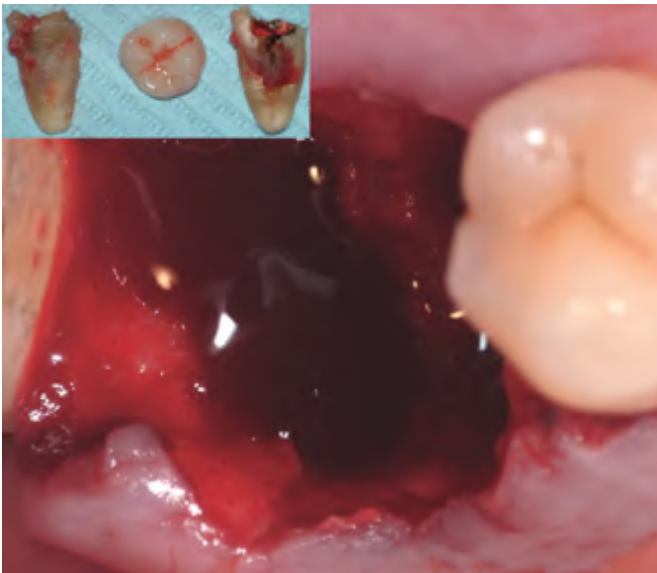


Figure 4.27. Clinical occlusal view of the extraction socket of the mandibular right first molar immediately after the tooth was sectioned and removed. The sectioned segments are in the top left corner inset.

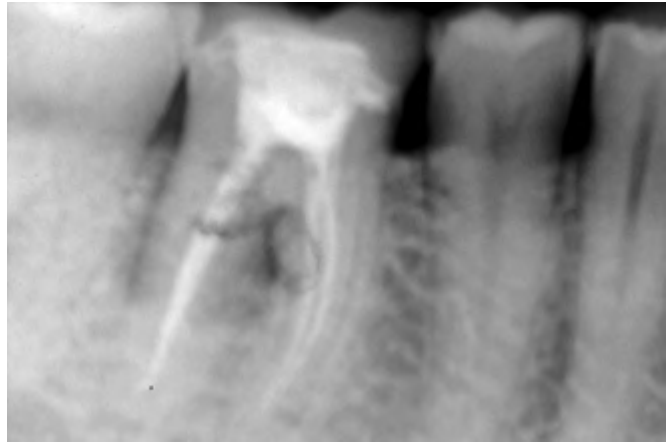


Figure 4.26. Preoperative radiograph of the mandibular first molar. The external resorption can be visualized in the furcation of the tooth.

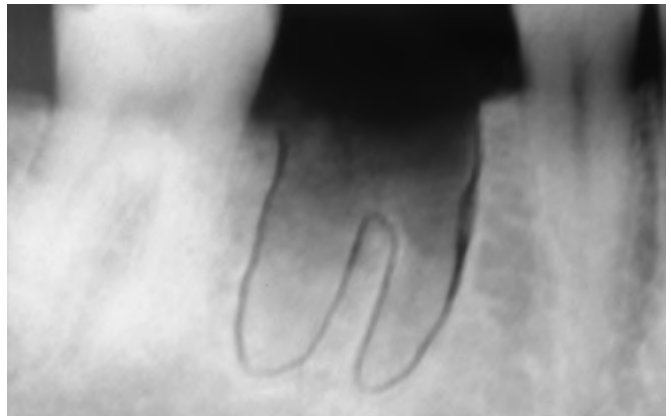


Figure 4.28. Radiograph taken of the extraction socket immediately post extraction. The outline of the roots was drawn by the periodontist.

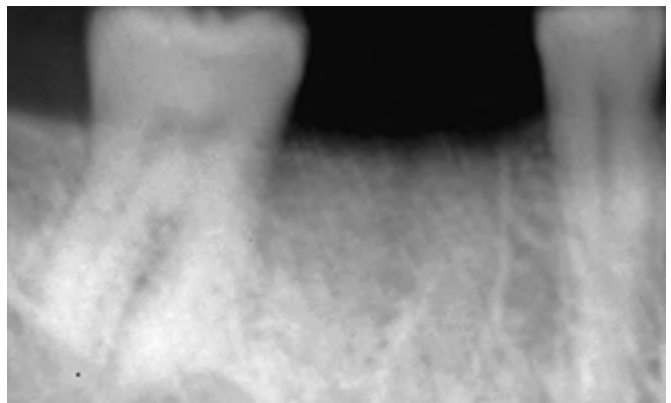


Figure 4.29. Radiograph taken 4 months post extraction and bone grafting. The bone graft appeared to be successful, and the site appeared ready for implant placement.



Figure 4.30. Clinical intraoral occlusal image of the extraction site approximately 4 months post extraction and bone graft. The ridge had healed in a broad U-shaped form, without apparent undercuts apical to the ridge. There was also an adequate amount of fixed keratinized tissue.

ASSESSMENT

The patient appeared to be an excellent candidate for placement of a 5-mm-diameter implant and implant-retained crown restoration (Figure 4.31). Top-down treatment planning is a protocol where the desired restorative result is considered first in treatment planning. This ideally leads to the consideration of the ideal implant restorative platform for a given situation and subsequent implant selection based on the bony anatomy. The top-down treatment planning protocol provides maximum biomechanical stability and allows for soft tissue flaring by utilizing an implant with an implant restorative platform consistent with the size of the tooth being replaced.

There were no medical contraindications for implant surgery. The bone graft appeared to have healed. The prognosis for successful replacement of the missing mandibular first molar with an implant-retained crown was excellent.

If the implant achieved an insertion torque value of at least 40 Ncm, and the patient did not need any additional bone grafting, the periodontist planned on using a one-stage surgical protocol. If these criteria are met, one-stage surgical protocols have proven to be as efficacious as two-stage surgical protocols (Testori and others 2002; Galli and others 2008).



Figure 4.31. This is an illustration of top-down treatment planning, where the desired restorative result is considered first in treatment planning. This ideally leads to the consideration of the ideal implant restorative platform for a given situation and subsequent implant selection based on the bony anatomy. In this case, a 5-mm-diameter implant was selected to replace the missing right mandibular first molar.

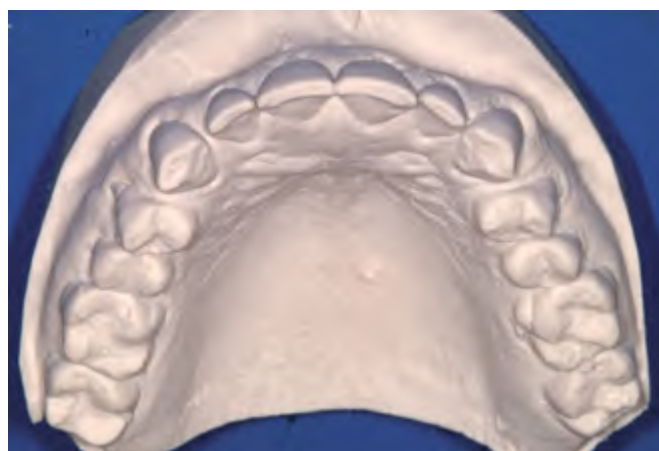


Figure 4.32. The maxillary diagnostic cast was poured in dental stone, from an alginate impression.

DIAGNOSTIC CASTS/SURGICAL GUIDE

Alginate impressions were made of the dentitions; diagnostic casts were poured in dental stone (Figures 4.32 and 4.33).

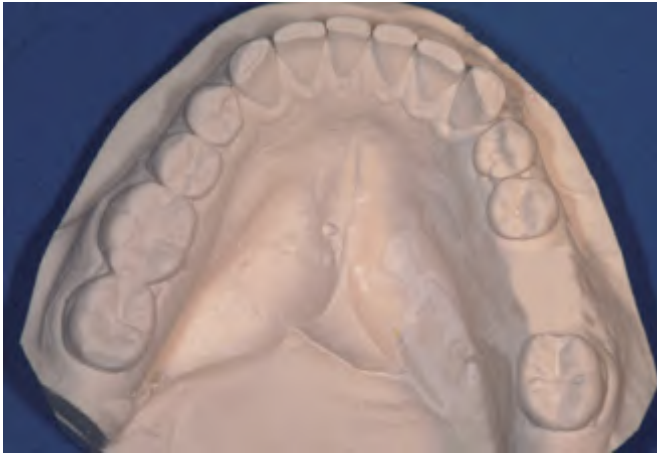


Figure 4.33. The mandibular diagnostic cast was poured in dental stone, from an alginate impression.

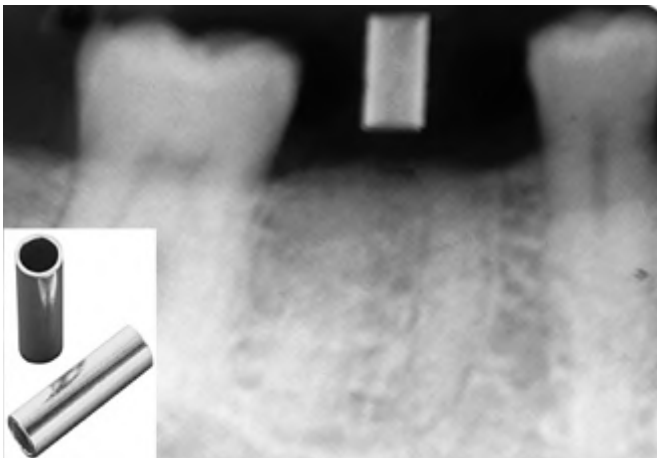


Figure 4.34. Preoperative radiograph with the surgical guide in place. The periodontist placed a stent guide tube (SGT25) into the surgical guide. The guide tube was designed for use with 2-mm twist drill (lower left corner inset).

The periodontist made a surgical guide and placed a surgical guide tube (SGT25, Biomet 3i) into the surgical guide, approximately in the middle of the edentulous space. It must be noted that the guide tube was placed based on the anatomy of the diagnostic cast and the two-dimensional radiograph. It provided the periodontist with a starting point for the osteotomy. However, the exact location of the osteotomy was modified based on the specific anatomy of the implant site. He took a radiograph with the surgical guide in place (Figure 4.34). He approved the tentative position of the implant and scheduled the patient for the implant surgery.

IMPLANT SURGERY

A 5-mm tapered implant (NanoTite™ Tapered Certain®, NINT511, Biomet 3i) was placed (Figures 4.35 and 4.36).



Figure 4.35. This is an illustration of the implant that was used to replace the missing mandibular first molar (NINT511).



Figure 4.36. This is a radiograph of the edentulous site taken just prior to the implant surgery. A 5-mm-diameter, 11.5-mm-length implant has been superimposed onto the radiograph to simulate the position of the implant in the alveolus.

The insertion torque registered at least 50Ncm on the implant drilling unit. Therefore, a one-stage surgical protocol was used.

PLACEMENT OF HEALING ABUTMENT

The healing abutment was selected consistent with the top-down treatment planning approach (Lazzara 1994). With the availability of osseointegrated implants in an assortment of diameters as well as lengths, the implant selection process has become more complex. To expand treatment options and optimize outcomes, implant selection should be guided by a number of surgical considerations and prosthetic requirements specific to each implant site. Small-diameter implants are appropriate in areas of



Figure 4.37. Illustration of the healing abutment that was used in this case (IWITH574, Biomet 3i). The illustration on the left side of the image is the healing abutment in profile. The gold-colored screw identified this healing abutment for use with a 5-mm-diameter internal connection implant. The illustration on the right side of the image shows three numerals on the occlusal surface: the large numeral “4” (left side) signified that this healing abutment had a 4-mm collar; the numerator “7” on the right side signified that the emergence profile diameter was 7.5 mm; and the denominator “5” signified that this healing abutment was designed to fit a 5-mm-diameter implant restorative platform.

narrow ridge dimension or where prosthetic space is limited. Wide-diameter implants are well suited to posterior regions with poorer bone quality and restricted vertical height. Wide-diameter implants provide a higher degree of implant-to-bone contact, increased initial stability, reduced screw stress, and anatomical emergence profiles, consistent with the teeth being replaced.

A 7.5-mm-diameter healing abutment, with a 4-mm collar height, was selected for this 5-mm-diameter implant (Figure 4.37). These dimensions were consistent with the cervical diameter of a mandibular first molar (Figure 4.38).

PLACEMENT OF ENCODE HEALING ABUTMENT AND ENCODE HEALING ABUTMENT IMPRESSION

To facilitate the implant restoration for the referring general dentist, the periodontist decided that a custom CAD/CAM abutment would be the treatment of choice for the mandibular right first molar implant restoration.

Jemt (2008) reported on long-term data that compared cemented and screw-retained single-implant crown resto-

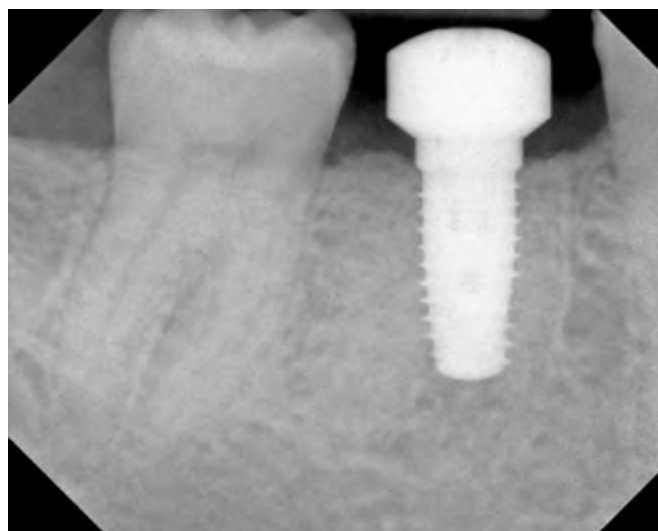


Figure 4.38. This radiograph was taken just prior to patient discharge, after implant placement. A 7.5-mm-diameter healing abutment, with a 4-mm collar height was placed. This was consistent with the cervical diameter of a mandibular first molar. The healing abutment was completely seated onto the implant restorative platform.

rations. He compared the clinical and radiographic performances of single-implant crown restorations made by either directly baked porcelain with custom-made TiAdapt® titanium abutments (Nobel Biocare AB, Göteborg, Sweden) (test) or cemented crowns onto CeraOne® (Nobel Biocare AB) abutments (control) after 10 years in function. Thirty-five consecutive patients were provided with 41 turned single Brånemark System® implants (Nobel Biocare AB) in partially edentulous maxillae. Randomly, 15 and 20 patients were provided with 18 test and 23 control implant crowns, respectively. Thereafter, clinical and radiographic data were collected and compared between the two groups. Jemt (2008) reported that none of the implants failed during the 10-year follow-up period (CSR = 100%). Few clinical problems were observed, and the overall average marginal bone loss was 0.26 mm (SD = 0.64) during 10 years in function. After the final tightening of the abutment screws, no significant differences were observed between the test and control groups ($P > 0.05$). Jemt (2008) concluded that there seemed to be no obvious clinical or radiographic differences between the test and control single-implant restorations during 10 years of follow-up. Occasionally, some restorations presented loose abutment screws and/or fistulas during follow-up. This implied a certain need for maintenance where a one-piece single-implant protocol (test) allowed both for a simple clinical procedure at placement without cementation problems, as well as for an easy and simple maintenance of

installed single-implant crowns in long-term function. Other researchers have reported few clinical problems with single-implant crown restorations (Scheller and others 1998; Gotfredsen 2004).

A unique healing abutment (Encode Complete Restorative System) was selected consistent with the implant restorative platform, emergence profile and soft tissue depth (Figure 4.39). The heights of EHAs, as compared with the conventional healing abutment, have to be taller because for accurate scanning, clinicians must be able to visualize all of the codes on the occlusal surfaces of EHAs. The heights of the domed occlusal portions of the healing abutments must extend at least 1mm above the gingival margins around each of the healing abutments because parts of the codes extend slightly onto the axial walls of the EHAs.

EHAs consist of two pieces: the abutment screw with a large hex (0.048in.) and the abutment body. The bodies of the healing abutments were designed with a hex interface to engage the hex connections of implants (Biomet 3i's internal connection; 4.1-mm external hex). Proper seating of the healing abutment must be verified with radiographs (Figures 4.40 and 4.41). The abutment screw was tightened to 20Ncm with a torque indicator prior to making the definitive impression.

Approximately 10 weeks post implant placement, the periodontist replaced the conventional healing abutment with an EHA. A definitive impression was made of the healing abutment, in a full-arch stock tray, with vinyl polysiloxane impression material (Figure 4.42). After the impression material set, the impression tray was removed from the



Figure 4.39. Clinical occlusal view of the occlusal surface of the Encode Healing Abutment in the right mandibular first molar site. All of the occlusal codes were clearly visible.



Figure 4.40. The healing abutment was correctly seated onto the implant in the radiograph on the left side of this image; the healing abutment was not seated correctly onto the implant in the radiograph on the right side of the image.

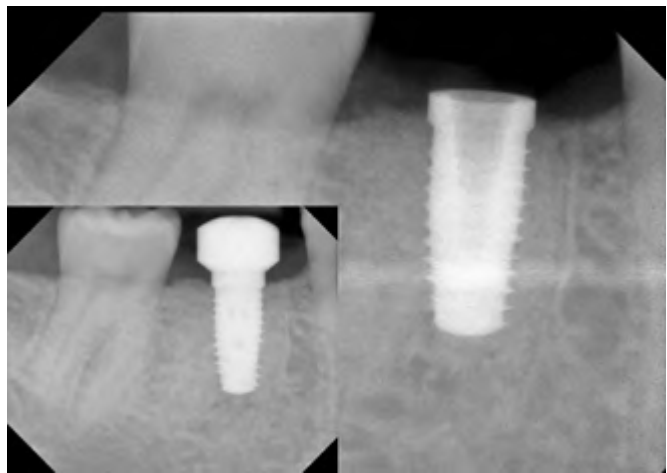


Figure 4.41. Radiograph taken at the time of implant placement. The implant was placed approximately 1 mm supracrestal. The inset (lower left) demonstrates that the healing abutment was accurately seated at the time of implant placement.

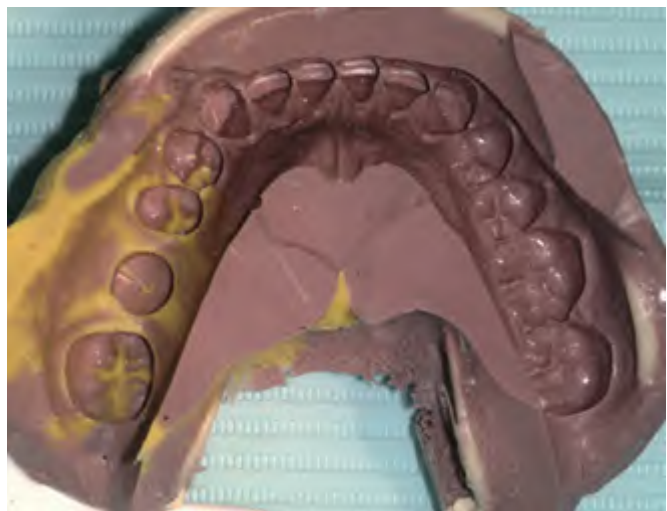


Figure 4.42. Laboratory occlusal image of the full-arch, fixed prosthodontic type of impression that was made of the mandibular arch. The Encode Healing Abutment in the area of the mandibular right first molar was completely recorded in the impression.

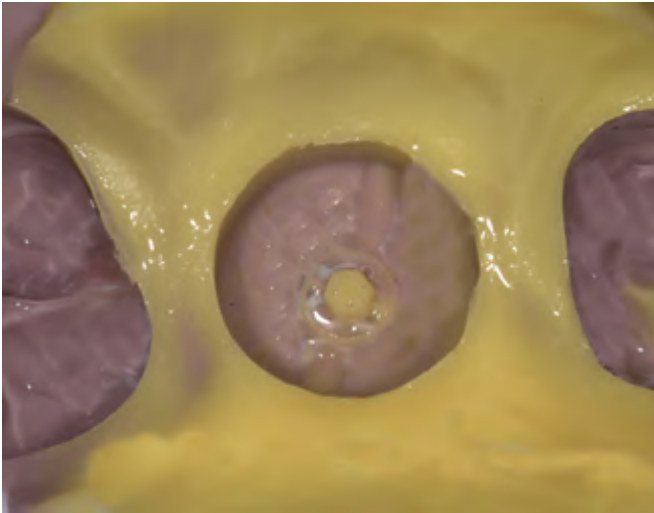


Figure 4.43. Close-up laboratory image of the impression of the Encode Healing Abutment in Figure 4.42.



Figure 4.44. A full-arch cast was poured in die stone, as per the manufacturer's instructions. Pins were not used in this cast.

mouth and the impression was examined to verify that an accurate impression had been made of the EHA occlusal codes, including the entire circumferences of the healing abutment, as well as the soft tissue contours (Figure 4.43).

MASTER CAST

The impression was poured with low-expansion die stone, as per the manufacturer's instructions (Figure 4.44). The cast was large enough to allow for insertion of the appropriate implant analog (Figure 4.45).

The cast was carefully inspected to verify that all of the occlusal codes had been satisfactorily replicated from the



Figure 4.45. In this protocol, the cast must be thick enough to withstand drilling a hole and placing the appropriate-sized implant analog into the cast.



Figure 4.46. This is a close-up laboratory view of the occlusal surface of the Encode Healing Abutment in die stone, in the mandibular right posterior quadrant of the master cast. All of the occlusal codes were visible. The voids/defects in the areas of the abutment screw/abutment interface were not important since all of the requisite information for identifying, designing, and milling the abutment was contained in the occlusal codes.

impression (Figure 4.46). For accurate scanning, EHA casts must provide the following:

1. Complete visibility of the occlusal surfaces (defect free)
2. 1-mm visibility of the axial walls
3. Accurate and defect-free duplication of the peri-implant soft tissues around each healing abutment

For this particular protocol, dowel pins were not placed as in an implant-level impression protocol. Instead, the analog will be placed using a robot. Therefore, casts made for use with this protocol have to be solid, including the cast base. Plates also cannot be used per this robotic analog placement technology.



Figure 4.47. The casts were correctly mounted within an articulator with Adesso Split Plates. The casts were centered vertically, consistent with the horizontal pin of the incisal guide pin. They were also centered directly in line with the mounting plates.

ARTICULATOR MOUNTING

The casts were hand articulated and mounted on an articulator compatible with Adesso® Split Mounting Plates (Baumann Dental GmbH, Ellmendingen, Germany) such as the Ivoclar Stratos 100 (Figure 4.47). Prior to mounting the casts, the articulator was calibrated and zeroed per the manufacturer's instructions. Prior to mounting the casts, it is important to make sure the vertical occlusal pin is set at zero and rests on the incisal guide table. This articulator was adjusted with the patented centering key. The manufacturer has stated that the Adesso split system has micrometer accuracy, between articulators, when adjusted properly (www.modelsystem-2000.com/english/pdf/prospekte/e_26660.pdf).

The casts were centered within the articulator, with the incisal edges of the maxillary anterior teeth aligned with the horizontal pin on the incisal guide pin. Casts must be centered on the mounting plates since the scanners read the casts relative to where the plates were located in the articulator. If a cast is not centered within the mounting plates, the cast and healing abutments will not be correctly scanned (Figures 4.48 and 4.49). The incisal guide pin was set to zero.

ENCODE COMPLETE WORK ORDER

The work order was completed and signed by the dental laboratory technician (Figure 4.50). In this case, the dental laboratory technician specified the following:



Figure 4.48. Illustration of casts incorrectly mounted within an articulator with Adesso Split Plates. The casts were centered vertically within the articulator but were not centered directly in line with the mounting plates. This mounted cast would not fit accurately within the scanner and scanning the Encode Healing Abutment would not be possible due to the incorrect mounting. The case would have to be returned to the dental laboratory or clinician for remounting.



Figure 4.49. This case was originally mounted in an articulator that was not calibrated properly. The casts were in centric occlusion, but the incisal guide pin was off the incisal guide table by approximately 5 mm.

Work Order

* 1. Account Information

* Laboratory Name: _____
 BIOMET 3i Account#: _____
 * Contact: _____
 * Phone: _____
 Fax: _____
 * Email: _____
 * Patient ID: _____
 * Ship To: _____

 Bill To: _____

* 2. Preparing Your Case For Shipment

- Use only die stone for Encode Complete Casts
- Verify that all of the codes on each healing abutment are completely visible on the cast
- Mount casts on Adesso Split Plates Articulator **only** (Stratos® or Baumann) and verify the vertical pin is set at zero and meets the occlusal table
- Following mounting on the designated articulator, please include the following in the shipment to BIOMET 3i:
 - ☐ Encode Cast
 - ☐ Opposing cast
 - ☐ Copy of the completed work order
- All unarticulated or misarticulated casts will be returned to the laboratory
- Please **do not** send the articulator
- Analogs cannot be placed in sectioned or pinned casts
- **Please make sure there is no metal in the cast.** The laboratory is responsible for any damage to BIOMET 3i Equipment or personnel caused by metal in the cast

* 3. Case Information

[illegible]

**** NOTE:** TiN Coating will add two working days to the processing of your abutment. If a box is not checked the abutment will not be TiN coated.

* 4. Design Guidelines

Margin Style – Select One

- ☐ Shoulder
- ☐ Chamfer (default)

Interocclusal Distance: _____ mm

NOTE: Default on all margins = 1mm Subgingival

Buccal Margin Location

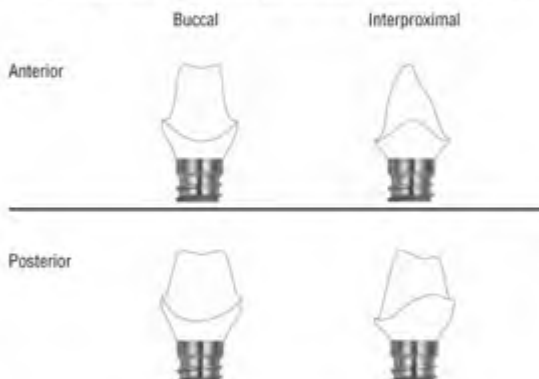
- ☐ Subgingival _____mm
☐ Flush with gingiva

Lingual Margin Location

- ☐ Subgingival _____ mm
- ☐ Flush with gingiva
- ☐ Supragingival _____ mm

5. Contour Guidelines

Please draw the approximate contour desired over the default images below.
Note margin style. Please draw in tissue contour.
(Minimum abutment height = 4mm and minimum collar height = .5mm)



6. Special Instructions

- ☒ Polish entire abutment (default) ☐ Only polish the subgingival collar

- ☐ See back or attached page for additional instructions.

7. Screw Ordering

- ☐
- I would not like to order screws at this time.

Certain Abutment Screws	Qty.
Gold-Tite® Hexed (IUNIHG)	_____
Titanium Hexed (IUNIHT)	_____
Laboratory Hexed Try-in Screw - 5 pack (IUNIT5)	_____

External Hex Abutment Screws	Qty.
Gold-Tite Square (UNISG)	
Gold-Tite Hexed (UNIHG)	
Titanium Hexed (UNIHT)	
Laboratory Square Try-in Screw - 5 pack (UNITS)	
Microminiplant™ Square Try-in Screw - 5 pack (MUNITS)	

* 8. Certification — must be signed

I certify that the stated information is correct and that the submitted materials are accurate and contain no metal. All items that have contacted the oral environment have been disinfected. This form authorizes BIOMET 3i to fabricate the patient specific abutment(s) and place analogs using and consistent with the information provided on this work order.

Technician Signature _____

Date _____

Internal Use Only

Job #: _____

Signature: _____

BIOMET 3i

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ART881
REV F 02/08

* REQUIRED FIELD

Figure 4.50. Work order for the Encode Abutment and Robotic analog placement.

1. The implant site by tooth number
2. Identified the implant abutment connection as Certain
3. Specified that the Final Encode Abutment should not receive the gold-colored titanium nitride coating
4. The implant site should have the implant analog placed by the robot
5. Chamfer margins
6. Facial and interproximal margins to be placed 1 mm subgingival
7. Lingual margins to be placed at the gingival crest
8. The interocclusal distances between the occlusal surfaces of the abutment and the occlusal surface of the opposing teeth were to be 2mm
9. The contour guidelines were to be standard
10. The abutment was to be polished
11. Robotic placement of the analog, consistent with the EHA in the cast

The casts and mountings were carefully wrapped in bubble paper and sent to the Patient Specific Products (PSP) Department, Biomet 3i, 4555 Riverside Drive, Palm Beach Gardens, FL.

SCANNING

The casts were received at Biomet 3i and placed onto the articulator, which is verified on a daily basis. The original articulator mounting was verified as accurate.

The casts were placed into a laser scanner (D-250™ 3D Scanner, 3Shape A/S, Copenhagen, Denmark) (Figures 4.51 and 4.52). This particular company offers 3-D scanning systems that create accurate 3-D models from real objects at the push of a button. The Web site stated that all of the scanners use optical technology to capture casts' geometries precisely and are said to offer an intuitive user-friendly interface (www.3shape.com).

According to the above Web site, 3Shape's dental solutions are a unique combination of 3Shape's expertise in 3-D scanning and 3-D CAD software that provide clinicians and dental laboratory technicians integrated solutions for the creation of accurate customized CAD/CAM dental restorations.

3Shape's dental restoration system is completely open (output files are in a standard format) and offers advanced 3-D technology. This system allows scans of full casts, dies, or wax patterns and designs full anatomical crowns, fixed partial denture (FPD) frameworks, or implant abut-



Figure 4.51. D-250 3Shape Scanner. The opaque black glass doors were open for this photograph and exposed the magnetic mounting plate designed for the Adesso Mounting Plates used in this protocol.



Figure 4.52. The interior section of the D-250 3Shape Scanner with a close-up view of the mounting plate designed to accept Adesso Mounting Plates.

ments from the scanned data. 3Shape's open system allows manufacturers the possibility to manufacture products in compatible milling units and materials, as well as the benefit from the increasing number of outsourcing production centers.

3Shape's DentalManager™ software program allows for automatic handling of all production files and transfer of the files to manufacturing equipment and/or outsourcing centers.

The casts were scanned (D-250 3D Scanner). The digitized data from the scanning of the EHA (in die stone) was imported to the personal computer workstation of one of the PSP designers. A verification process was carried

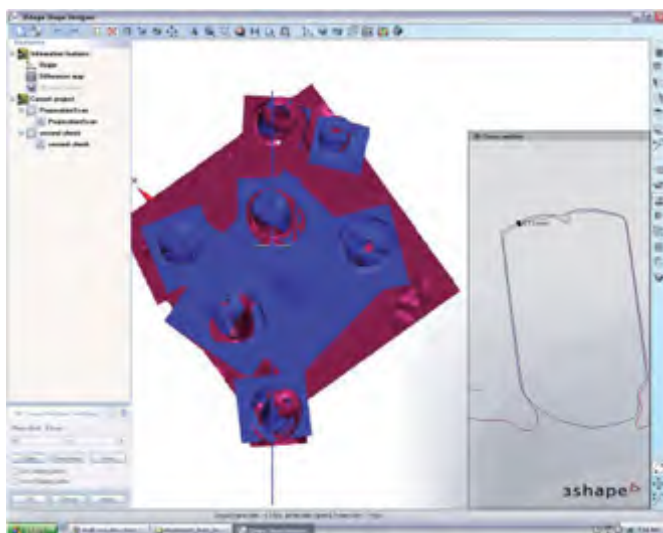


Figure 4.53. This is a computer screen image of the verification process used in the Encode Complete protocol. The blue portion of the image is the result of the scanned Encode Healing Abutment (die stone) from a cast received at Biomet 3i. The red portion is the image from an actual Encode Healing Abutment that was placed on the analog in the Robocast. The cross-sectional image on the right side of the photograph indicates that the scanned image of the Encode Healing Abutment (die stone) was replicated by the scanned image of an actual Encode Healing Abutment placed on the analog of the Robocast.

out that verified the EHA as scanned represented an accurate representation of the EHA in the patient's mouth (Figure 4.53).

ABUTMENT DESIGN/MILLING

The abutment was custom designed per the instructions on the work order:

1. Margin type and location: heavy chamfer margins; supragingival for the facial and lingual margins; subgingival for the interproximal margins
2. Total occlusal convergence: approximately 6 degrees
3. Interocclusal clearance between the occlusal surface of the abutment and the opposing occlusal surfaces: approximately 2mm (Figures 4.54 and 4.55)

The abutment was designed in CAD design software. In some cases, the CAD designs may be e-mailed to dental technicians for review and discussion. This discussion has to be arranged prior to design.

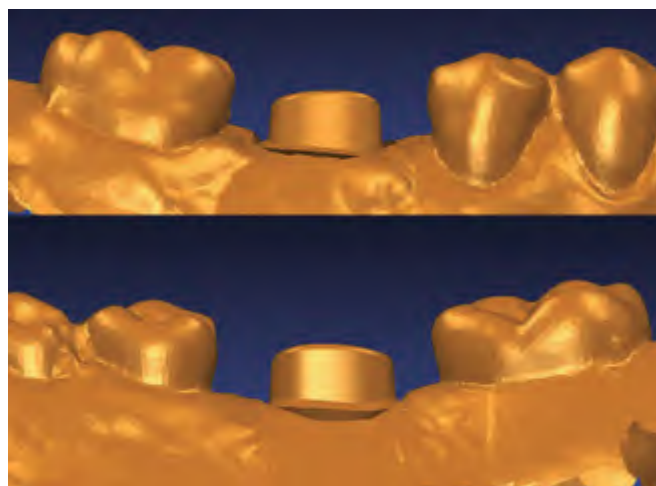


Figure 4.54. The proposed abutment design was e-mailed to the dental laboratory technician for approval. The top image was the view from the facial surface; the bottom image was the view from the lingual surface. The facial and lingual margins were designed as supragingival; the interproximal margins were designed as subgingival.

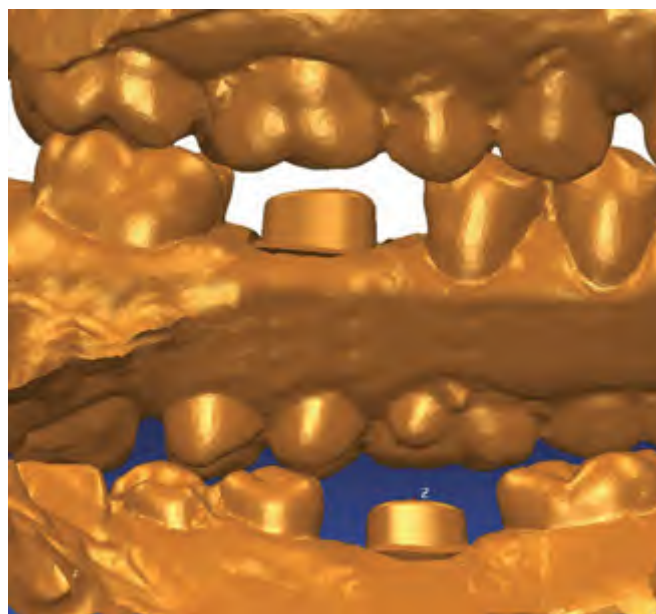


Figure 4.55. These two images depicted the virtual articulation of the right maxillary and mandibular quadrants. The abutment design could have been modified regarding interocclusal distance between the abutment and the opposing dentition, location of the cusp tips, as well as other design changes as needed by the dental laboratory technician responsible for the definitive crown restoration.

The design data were sent to a milling machine (Mikron HSM 400, Mikron Agie Charmilles, Nidau, Switzerland) for milling the titanium alloy abutments per the CAD designs described above (Figure 4.56). The manufacturer has stated that with these machines, accuracy, extreme dynamics, and high machining speeds have been combined with other important manufacturing aspects such as outstanding swarf removal, high flexibility, good ergonomics, and well-integrated automation. According to the manufacturer's Web site, the unique flexibility of the HSM 400U ProdMed Dental milling unit is a key success factor by both time-to-prototype and productivity assess-



Figure 4.56. Milling unit for the Encode Abutment.

ments. Reverse engineering has enabled dental solution providers to quickly and accurately bridge the gap between the physical and digital worlds by reading any point cloud data set, whether it is generated by a touch trigger, laser, or optical hardware system (www.gfac.com/gfac/products/high-speed-machining-centers/hsm-prodmed/mikron-hsm-400u-prodmed-dental.html?L=http%3A%2F%2Fwww.t-cross.com%2Fcgi%2Fannounce%2Fimages%2Fasawux%2Fuki%2F).

The abutment was milled, finished, and polished (Figure 4.57).

ROBOTIC PLACEMENT OF LAB ANALOG INTO CAST (ROBOCAST)

The cast was placed into the robot cast holder; the operator calibrated the drill component of the robot to remove the stone in the area of the stone EHA in the master cast (Figures 4.58–4.62). A hole was drilled into the cast (Figure 4.63). The digital data for this part of the process were obtained from the original scan of the EHA in the stone cast.

A 5-mm implant analog (IILAW5, Biomet 3i) was selected and placed into the analog holder (Figures 4.64 and 4.65). Cyanoacrylate cement was placed into the hole (Figure 4.66); a 5-mm-diameter analog was picked up by the robot (Figures 4.67 and 4.68) and placed into the hole in the stone cast. The 5-mm-diameter analog was secured to the cast with the accelerator portion of the cyanoacrylate cement (Figures 4.69–4.71). Note that a laboratory soft tissue replica was not needed because the emergence profile for the abutment had been previously developed in the CAD abutment design portion of the process. The Robocast process has been proven to be accurate to 0.2mm (Suttin and others 2007).



Figure 4.57. The Encode Abutment just prior to shipping. It was milled from a blank of titanium alloy, according to the design specifications. The implant/abutment interface was not altered from the original machining. Facial, mesial, and distal surfaces (left to right).



Figure 4.58. Laboratory robot that removed the stone corresponding to the stone Encode Healing Abutment by drilling a specific-sized hole, consistent with the digital data from the original scan of the Encode Healing Abutment in the cast.



Figure 4.60. The drill, specific to the implant size and site, in place in the robotic arm, approaching the abutment site in the stone cast.



Figure 4.59 The robot is calibrated for each case, prior to drilling the hole(s).

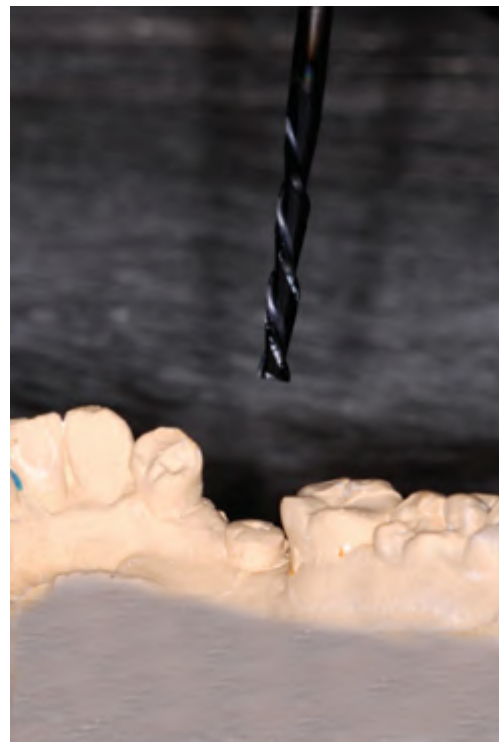


Figure 4.61. The drill in the robot, just prior to engaging the stone cast.



Figure 4.62. The drill has engaged the stone cast in the area of the planned analog placement. Stone will be removed consistent with the size of the planned implant lab analog.



Figure 4.63. One hole drilled into a cast, specific to the planned analog/implant site.

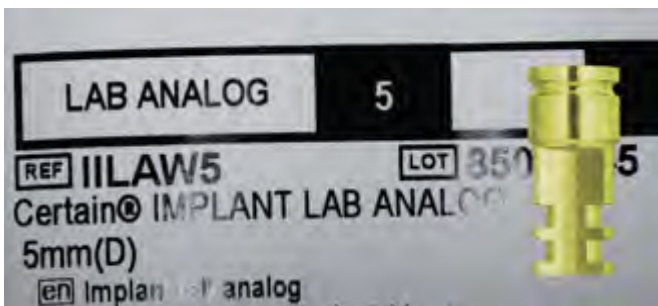


Figure 4.64. Package as received from the manufacturer that contained a 5-mm-diameter implant lab analog. Five-millimeter implant lab analog (upper right inset).



Figure 4.65. Five-millimeter internal connection implant lab analogs in place in the analog holder of the robot.



Figure 4.66. Cyanoacrylate cement placed into the hole, prior to insertion of the implant analog by the robotic arm.



Figure 4.67. The appropriate implant lab analog (5-mm Certain) was picked up by the robotic arm.



Figure 4.68. The 5-mm implant lab analog, in the robotic arm, as it approached the hole in the cast. Five-millimeter implant lab analog (upper left inset).



Figure 4.69. The 5-mm implant lab analog held in place by the robotic arm, in its correct position, as the cement activator was applied.

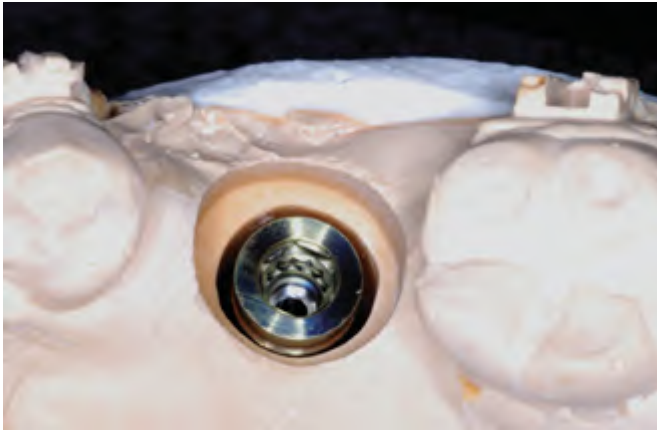


Figure 4.70. Occlusal laboratory view of a 5-mm-diameter, internal connection implant lab analog in its correct position within a stone cast.



Figure 4.71. Occlusal buccal laboratory view of a 5-mm-diameter, internal connection implant lab analog in place in the Robocast. There was no need for a soft tissue replica, as the contours of the peri-implant soft tissues were previously taken into account during the abutment design process.

The Final Encode Abutment was placed onto the analog in the Robocast where it was checked for marginal integrity, contours, and interocclusal clearance. Due to the internal connection of the abutment, this step was carried out without using an abutment screw. The casts and abutment were packaged and shipped to the restorative dentist's commercial dental laboratory for fabrication of the definitive porcelain-fused-to-metal crown (Figures 4.72 and 4.73).



Figure 4.72. Buccal/occlusal laboratory view of the machined Final Encode Abutment in place on the implant lab analog in the Robocast. Note the absence of soft tissue replicating material around the abutment. The stone in this implant site did not contact the abutment. However, the locations of the peri-implant soft tissue margins were previously identified in the original scan and were already incorporated into the abutment's margins.



Figure 4.73. Laboratory lingual view of the machined abutment in place on the Robocast. Soft tissue replicas are not required with this protocol because the peri-implant soft tissue contours were taken into account during the CAD design of the abutment's margins. The abutment margins were placed relative to the original gingival contours, and therefore did not have to be replicated in the cast.

FABRICATION OF PORCELAIN-FUSED-TO-METAL CROWN

The above materials were unpacked at the commercial dental laboratory, and the abutment was placed onto the analog with a try-in screw. The use of die spacer is a convenient method to overcome problems caused by incomplete crown seating during cementation of a casting



Figure 4.74. At the commercial dental laboratory, two layers of die spacer were applied directly onto the axial and occlusal surfaces of the definitive abutment. In this image, the abutment was placed onto an implant lab analog to facilitate handling.

whose fit was satisfactory on the die or abutment. In this case, two layers of die spacer were applied approximately 1 mm above the cervical margins, directly to the axial and occlusal surfaces of the abutment (Figure 4.74).

A full-contour wax pattern was made on the Final Encode Abutment. The wax pattern optimized the axial contours, occlusal surfaces, and the emergence profiles of the proposed implant restoration (Burch 1971; Burch and Miller 1973).

The wax pattern was cut back to allow room for porcelain without compromising the integrity and strength of the casting. Aesthetic and functional requirements dictated the design of the veneered surfaces. The ceramic veneer was designed to extend far enough interproximal to avoid metal display of the underlying coping. Aesthetic demands of the patient required the dental laboratory technician to provide a porcelain occlusal surface.

The pattern was cast and finished in preparation for porcelain (Figures 4.75 and 4.76). Sharp line angles on the veneering surfaces of the metal coping were eliminated since they can readily contribute to internal stress within the definitive restoration (Warpeha and Goodkind 1976). Porcelain was stacked in conventional fashion. The crown was finished, polished, packaged, and returned to



Figure 4.75. Occlusal laboratory view of the cast coping in place on the Encode Abutment in place on the cast.



Figure 4.76. Lingual laboratory view of the cast coping in place on the abutment in place on the cast.

the periodontist for clinical try-in and insertion (Figures 4.77–4.80).

CLINICAL INSERTION

The healing abutment was removed and the peri-implant soft tissues had healed consistent with the shape of the healing abutment (Figures 4.81 and 4.82). This was the first time the healing abutment had been removed since the implant was placed. Removal and reinsertion of restorative implant components have been implicated in peri-implant bone loss (Linkevicius and Apse 2008).

The definitive abutment was placed onto the implant with the use of an abutment placement index. This index was made in the laboratory with a combination of light- and autopolymerizing acrylic resin. In the laboratory, after the technician seated the abutment into its correct position on the implant lab analog, resin was applied to the occlusal



Figure 4.77. Occlusal laboratory view of the porcelain-fused-to-metal crown in place on the cast. The occlusal table of the implant restoration was slightly narrower than the occlusal table of the right second mandibular molar. This design decreased the amount of a cantilever relative to the width of the implant restorative platform.



Figure 4.78. Buccal occlusal laboratory view of the porcelain fused to metal crown in place on the cast. Anatomical emergence profiles developed in the wax pattern were carried through to the cast coping and to the porcelain-fused-to-metal crown. The CAD design of the abutment allowed the ceramist to develop optimal emergence profiles in the definitive restoration.

surfaces of the adjacent teeth on the cast. It was important not to place any resin apical to the heights of contour of the adjacent teeth so as to avoid locking the index into undercuts. Prior to placing the resin onto the stone teeth, a large hex driver was placed into the try-in screw within the abutment. This allowed the screw access opening to remain patent throughout the process. The abutment placement index facilitated the correct placement of the

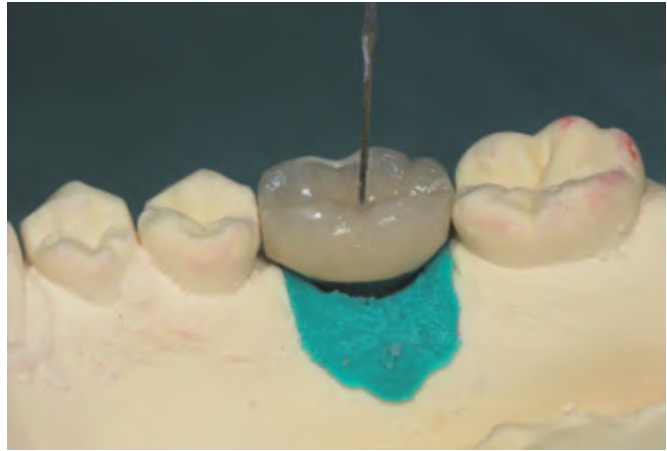


Figure 4.79. Lingual occlusal laboratory view of the porcelain-fused-to-metal crown in place on the cast. Anatomical emergence profiles developed in the wax pattern were carried through to the cast coping and to the porcelain-fused-to-metal crown. The CAD design of the abutment allowed the ceramist to develop optimal emergence profiles in the definitive restoration.

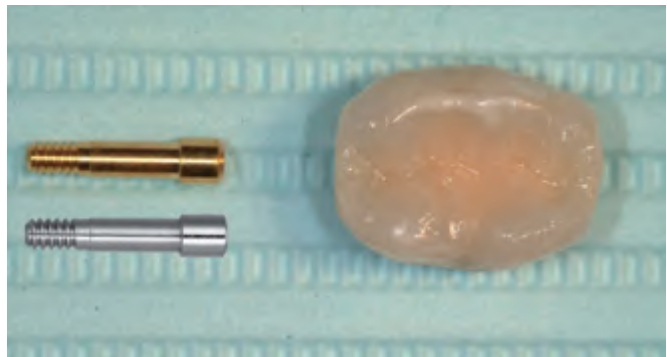


Figure 4.80. Laboratory images of the clinical abutment screw (IUNIHG, top) and the clinical/laboratory try-in screw (IUNIHT [Biomet 3i], bottom of left side of image). The implant-retained crown restoration (right) prior to packing for shipment to the restorative dentist's office.

abutment into the internal connection of the implant intra-orally, quickly and predictably (Drago 1996) (Figures 4.83–4.86).

Try-in screws were used to attach the abutment to the implant (IUNITS, Biomet 3i). A radiograph was taken that verified that the abutment was seated onto the implant restorative platform (Figure 4.87).

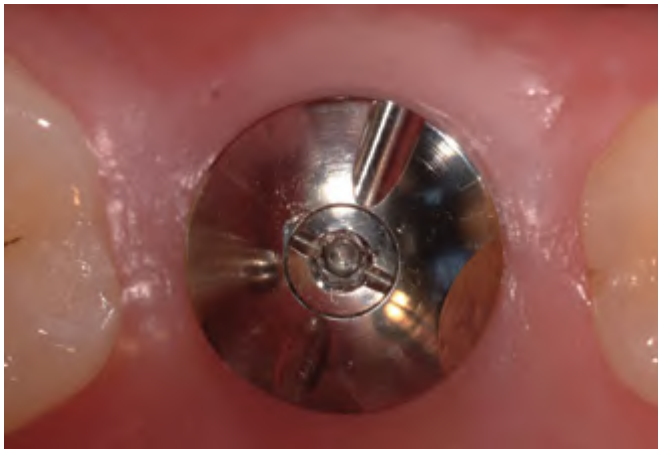


Figure 4.81. Clinical occlusal view of the patient's presentation at the insertion appointment. The Encode Healing Abutment remained in place during the interval from the impression appointment to the try-in appointment.

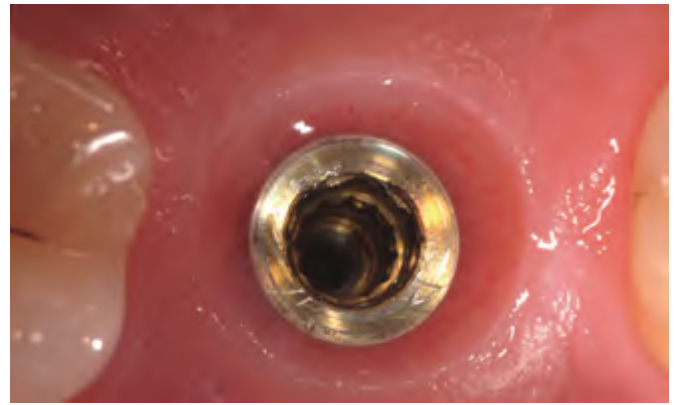


Figure 4.82. Clinical occlusal view of the implant restorative platform and peri-implant soft tissues after the healing abutment was removed. The soft tissue contours were consistent with the shape of the healing abutment; local anesthesia was not needed for this appointment.



Figure 4.83. Laboratory image of the abutment, in its correct position, within the resin abutment placement index. It was important not to place any resin of the abutment placement index into undercuts in the cast, so as to avoid locking the index in place intraorally.

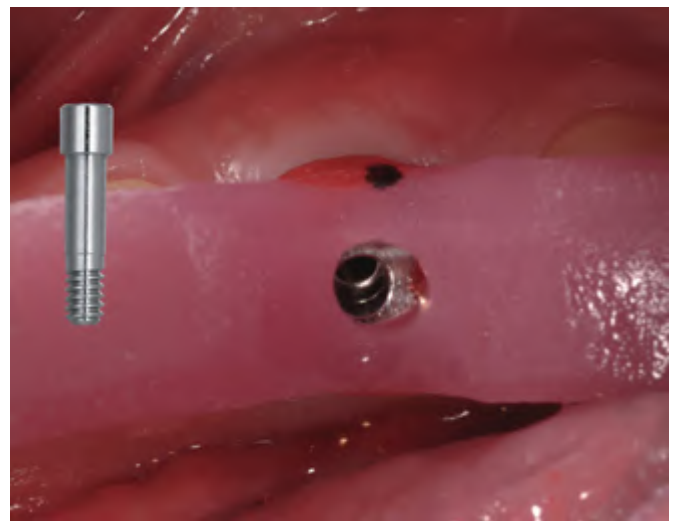


Figure 4.84. Clinical occlusal view of the abutment placement index in place intraorally. The try-in screw (upper left inset) was not in place at the time of this photograph.



Figure 4.85. Clinical buccal image of the definitive abutment in place. The buccal and interproximal cervical abutment margins were located at the peri-implant soft tissue margins.



Figure 4.86. Clinical lingual image of the definitive abutment in place. The lingual cervical abutment margins were designed to be slightly supragingival.

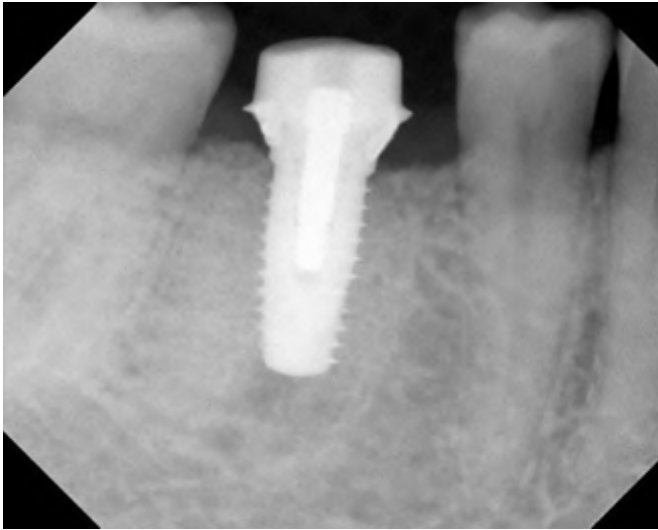


Figure 4.87. Periapical radiograph with the definitive abutment in place demonstrated that the abutment was seated properly onto the implant restorative platform. An ill-fitting abutment would be identified by a radiolucent space between the abutment and implant restorative platform.

The restorative dentist placed the crown and assessed the marginal fit. Interproximal contacts were adjusted until the crown was seated. An additional radiograph confirmed that the crown was seated onto the abutment (Figures 4.88–4.90).

The occlusion was evaluated with the patient seated upright and reclined; it was adjusted so that the mandibular buccal cusps were in contact with the opposing central fossae of the maxillary right posterior teeth. Right working disclusion was obtained with the maxillary and mandibular cuspid teeth. There were no balancing side contacts when the patient went into left working.

The crown and abutment were removed from the implant and the crown was polished. The abutment was resealed onto the implant with the abutment placement index; a definitive abutment screw (IUNIHG, Biomet 3i) was placed onto the driver tip of a torque instrument (CATDB, Biomet 3i). This screw was torqued to 20Ncm with the use of a torque controller calibrated to deliver 20Ncm of torque (Figures 4.91 and 4.92). The screw access opening was blocked out with cotton (Figure 4.93). The crown was cemented to the abutment with temporary cement (Figure 4.94). The excess cement was removed and the patient was discharged (Figure 4.95).

The treatment described in this chapter illustrated the use of new technologies in fabricating a cement-retained

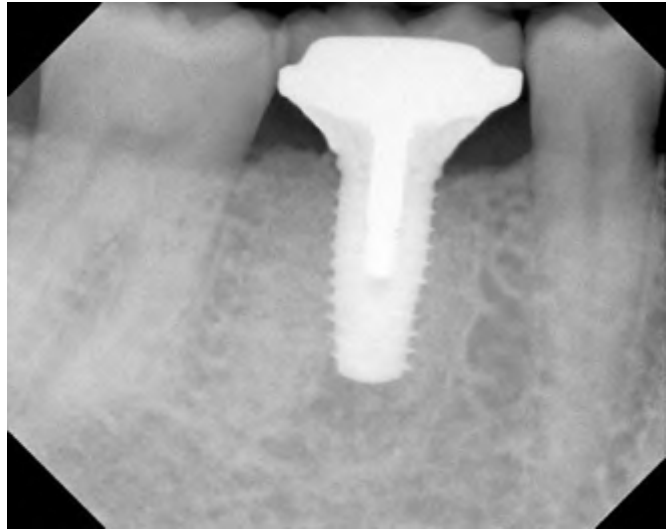


Figure 4.88. Radiograph with the implant-retained crown on the abutment demonstrated that the crown was seated properly onto the abutment. An ill-fitting crown would be identified by a radiolucent space between the crown and the abutment.



Figure 4.89. Clinical buccal image with the crown in place. Note the anatomical emergence profile of the implant restoration.



Figure 4.90. Clinical lingual image with the crown in place. Note the anatomical emergence profile of the implant restoration and that the lingual cervical margins of the crown restoration are supragingival.



Figure 4.91. The clinical abutment screw was placed onto the driver tip of the torque device. This particular torque device (Biomet 3i) consists of two parts: the contra-angle body (upper left insert) and torque controllers (20-Ncm torque controller depicted, lower left insert).



Figure 4.92. The driver tip was used to attach the abutment screw to the contra-angle torque instrument. The 20-Ncm torque controller was in place on the contra-angle body.

implant crown restoration without an implant-level impression. It featured a CAD/CAM technology that designed and milled a custom, titanium alloy abutment and conventional porcelain-fused-to-metal crown. This protocol has numerous benefits for clinicians and dental laboratory technicians, including that it allows laboratories to fabricate state-of-the-art CAD/CAM abutments without purchasing expensive scanners and milling units. Restorations constructed in this manner are relatively simple to fabricate



Figure 4.93. Clinical occlusal image of the cotton pellet used to block out the hex of the abutment screw prior to crown cementation. The block out material prevented cement from going into the screw access opening and potentially clogging the hex of the abutment screw.

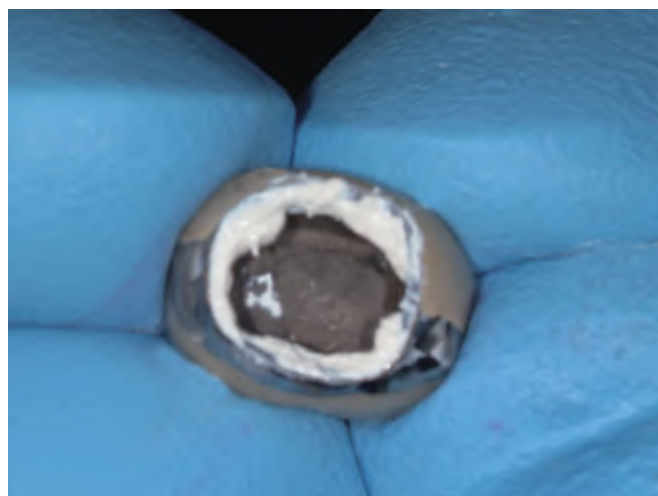


Figure 4.94. Minimal cement was placed onto the intaglio surface of the crown's margins to cement the crown to the abutment. Sometimes clinicians use too much cement in this procedure and have to spend significant time and effort to ensure that all of the cement has been removed from the peri-implant sulcus.

and provide excellent aesthetics and function. Labor costs are decreased as well. Dental laboratories can increase their implant business, and therefore profitability, by increasing the number of general dentists who were not previously involved in implant restorations, as well as providing high-quality custom titanium CAD/CAM abutments for their experienced restorative dentists.



Figure 4.95. Clinical occlusal view of the definitive crown in place.

The following clinicians and dental laboratory technicians were responsible for the treatments illustrated in this chapter:

Periodontist: Garry O'Connor DDS, MS, LaCrosse, WI

Dental Laboratory Technicians: Patrick Arneaud, Tom Bruner, CDT, North Shore Dental Laboratories, Lynn, MA

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Chapter 5: Maxillary Implant-Retained Primary Bar (CAM StructSURE Precision Milled Copy Milled Bar Framework) with Secondary Casting Maxillary Overdenture; Mandibular CAM StructSURE Precision Milled Bar for Mandibular Hybrid Screw-Retained Prosthesis

INTRODUCTION

Treatment of edentulous maxillae is probably one of the technically most demanding implant treatments clinicians and dental laboratory technicians are asked to do. Osseointegration is an established phenomenon; however, differing cumulative survival rates (CSRs) have been noted for maxillary and mandibular implants (Adell and others 1981, 1990). Implant-retained mandibular overdentures with nonsplinted implants have demonstrated CSRs consistent with those reported in fixed implant-retained prostheses (Figures 5.1 and 5.2). Testori and others (2001) followed patients for 4 years and reported a cumulative implant success rate of 98.7% for all of the implants placed in their study, with a 99.4% success rate in the posterior mandible and a 98.4% success rate in posterior maxillae. Cooper and others (1999) reported a CSR of 95.7% for unsplinted mandibular implants with overdentures. Naert and others (2004) reported on a 10-year randomized controlled clinical trial consisting of 36 patients who had mandibular overdentures supported by two implants. They reported the CSR for the mandibular implants at 100%.

The CSRs for maxillary implants have been dramatically different (Figures 5.3 and 5.4). Studies of maxillary overdentures supported by endosseous implants often show a high implant failure rate. Mericske-Stern and others (2002) conducted a clinical study where they studied the survival rates of maxillary implants supporting overdentures in maxillae. Forty-one patients were consecutively admitted for treatment. The standard procedure was to place four implants and to mount a U-shaped bar for overdenture connection. When the overdentures were delivered to the patients, peri-implant parameters were recorded and radiographs were taken. A life table analysis was applied to calculate the CSR. Three implants failed in the early healing phase, and three patients lost six implants during the loading period. The 5-year CSR of all implants was 94.2%. The mean marginal crestal bone loss was about 0.7mm and was statistically significant at the mesial and

distal sites ($P < 0.001$). They concluded that in planned maxillary overdenture treatment, it is possible to achieve a satisfactory CSR.

There have also been reports that maxillary implants need to be splinted together in order to achieve satisfactory CSRs. Jemt and others (1992) reported the results of a clinical study where overdentures were consecutively inserted into 92 severely resorbed maxillae and followed for 1 year. The overdentures were supported by 430 implants. Of these, 69 (16%) became loose and were removed during the follow-up period. The mobile implants caused seven complete failures of the overdenture treatments, in that prostheses had to be replaced. Postinsertion maintenance was more extensive for the overdentures than for fixed prostheses supported by implants. Problems arose in relation to the mucosa around the implants, and there were also fatigue fractures of the acrylic resin and the retentive clips. Fewer speech problems were reported in the overdenture group when compared with those with fixed prostheses.

Cavallaro and Tarnow (2007) reported on the results of a clinical study where five consecutive patients were treated with a minimum of four implants in edentulous maxillae. None of the implants were splinted together, and resilient overdenture attachments were placed after at least 12 weeks of unloaded healing. Patients were followed for 12–48 months post occlusal loading. Cavallaro and Tarnow (2007) reported that none of the implants were lost, for a CSR of 100%. They concluded that unsplinted maxillary implants can be used to retain maxillary overdentures.

CLINICAL PATIENT PRESENTATION

This patient was a 72-year-old female with a long-term history of smoking (>40 years). She presented to the periodontist with a chief complaint, “My upper teeth hurt and I want them taken out. I don’t want to wear dentures” (Figure 5.5). She had presented approximately 12 months



Figure 5.1. Clinical occlusal view of four resilient overdenture attachments on four unsplinted mandibular implants.



Figure 5.2. Clinical occlusal view of a mandibular screw-retained fixed prosthesis rigidly splinting five mandibular implants.



Figure 5.3. Clinical occlusal view of a maxillary CAD/CAM bar retained by five maxillary implants. This bar provided retention and stability for a maxillary overdenture.



Figure 5.4. Clinical anterior view of maxillary and mandibular fixed prostheses supported by dental implants. The maxillary fixed prostheses consisted of three independent units supported by a total of seven implants. The mandibular fixed prosthesis was a screw-retained prosthesis supported by six implants.



Figure 5.5. Clinical preoperative anterior view of this patient prior to extractions but post grafting of the maxillary sinuses. The patient's home care and oral hygiene procedures left much to be desired.

previously with a similar complaint regarding her mandibular dentition. At that time, a treatment plan was presented to her regarding extraction of the mandibular teeth, immediate placement of implants, and immediate occlusal loading with a fixed mandibular prosthesis (Lazzara and others 2004). At the time of the current presentation, all of the mandibular implants appeared to be stable and the patient was ready to proceed with the definitive mandibular implant prosthesis. The right and left maxillary sinuses had been grafted subsequent to the mandibular surgery in anticipation of maxillary implants. Physical and radiographic examinations were conducted (Figure 5.6).



Figure 5.6. Preoperative panoramic radiograph of this patient post sinus grafting but prior to the extraction of the remaining maxillary teeth. The surgeon identified the bone levels with a black pen.

DIAGNOSES

The following diagnoses were established:

1. Long-term history of heavy smoking (>30 cigarettes per day for at least 40 years)
2. Acute localized severe periodontitis of the maxillary teeth
3. Adequate bone volume for placement of maxillary implants
4. Apparently osseointegrated mandibular implants
5. Poor oral hygiene
6. Partially edentulous maxillae
7. Severe dental caries
8. Moderate xerostomia

ASSESSMENT

This patient's dentition was considered nonrestorable, and all of the teeth were indicated for extraction. The patient was considered to be a candidate for extraction and immediate implant placement; this patient was probably not a candidate for immediate occlusal loading. She was not considered to be a candidate for immediate occlusal loading because of the long-term history of smoking, the probability that the maxillary bone would be a combination of Type III and IV bone, and her lack of compliance in terms of home care. Implants placed into areas with softer bone generally do not obtain the requisite primary stability for successful immediate occlusal loading (Ostman and others 2005). Maxillary implants placed into grafted maxillary sinuses have lower CSRs than implants placed into native bone (Becktor and others 2004).

Due to the amount of preexisting bone loss around the maxillary anterior teeth, the treatment plan called for place-



Figure 5.7. Laboratory lateral view of an articulator mounting with an edentulous maxillary cast and a mandibular waxed denture. Note the severe anterior/posterior and vertical resorption of the anterior maxillary segment relative to the location of the mandibular teeth. This patient would not be a candidate for a maxillary fixed implant-retained prosthesis due to the location of the remaining bone and the required positions of the maxillary anterior teeth for optimal lip support and aesthetics.

ment of six maxillary implants, with an even distribution in both anterior and posterior segments. Due to the amount of anterior bone loss and the amount of lip support that was needed to satisfy the patient's aesthetic demands, a removable overdenture was the treatment of choice. The implants would support a primary computer-aided design/computer-aided manufacturing (CAD/CAM) bar; a secondary cast bar would be made that would be retained inside the maxillary overdenture for strength, retention, and stability. If all went well, the maxillary overdenture would have minimal palatal coverage.

There are risk factors associated with maxillary full-arch implant prostheses (Renouard and Rangert 2008). A prosthesis attached to a primary bar should be considered for patients with significant bone resorption and/or with a large skeletal discrepancy between the maxillary and mandibular jaws (Figure 5.7). An overdenture implant-retained bar allows implants to be placed into more favorable positions relative to the available bone volume (Figure 5.8). The clinical benefits of this design are that the patient receives excellent lip support from the flange of the overdenture, may have reduced palatal coverage of the denture base (Figure 5.9), and has easier access for oral hygiene. This may also facilitate better, more natural phonetics (Heydecke and others 2004).

Renouard and Rangert (2008) have published criteria that rate the risk factors associated with maxillary implant overdenture treatment (Tables 5.1 and 5.2). This patient



Figure 5.8. Clinic occlusal view of a maxillary implant-retained bar. Sufficient bone was not available in the incisor areas for implants to retain and support a fixed partial denture. However, there was bone available in the cuspid and premolar regions bilaterally. Implants were placed into these areas to provide increased retention and stability to the maxillary implant-supported overdenture.



Figure 5.9. Laboratory view of the intaglio surface of a secondary cast bar inside a maxillary overdenture. Note the open palate of the maxillary overdenture. This patient required a significant amount of lip support and was only able to have anterior and posterior implants placed. The seven implants were used to retain a CAD/CAM primary bar.

TABLE 5.1. Prognoses Associated with Maxillary Implant-Supported Overdenture Prostheses

Limitation	Acceptable Prognosis	Compromised Prognosis	Poor Prognosis
Interimplant distance (mm)	>10	6–8	<5
Bone width (mm)	7	6	<5
Interocclusal distance (mm)	10–15	6–10	<6

Note: These dimensions are indicated for 4-mm-diameter implants.

TABLE 5.2. Prognoses for Maxillary Implant-Supported Overdenture Prostheses

Specific Risk	Acceptable Prognosis	Compromised Prognosis	Poor Prognosis
Bone volume	A, B, C	D	E
Bone density	Type I, II, or III	Type IV	Type IV
Number of implants	4–6	2–4	2

Bone volume and bone density per Albrektsson and others (1986).

was assigned a compromised prognosis for the reasons noted above.

DIAGNOSTIC CASTS/SURGICAL GUIDE

Diagnostic casts were made in conventional fashion from alginate impressions. The cast was mounted into an articulator via jaw relation records with a record base and occlusion rim. The maxillary teeth were extracted from the diagnostic cast, and the immediate denture was fabricated in conventional fashion. The vertical dimension of occlusion (VDO) was not going to be changed, so the surgical

guide was made as a duplicate of the maxillary immediate denture (Figures 5.10 and 5.11).

IMPLANT SURGERY

The maxillary teeth were extracted, and a full-thickness mucoperiosteal flap was reflected. The initial osteotomies were made, and the relative parallelism of the implants was determined with the use of directional guide indicators (Figure 5.12). Six maxillary implants were placed (Figure 5.13). None of the implants achieved insertion torque values in excess of 20Ncm, and therefore, this patient was



Figure 5.10. Laboratory anterior view of wax maxillary immediate complete denture prior to processing.

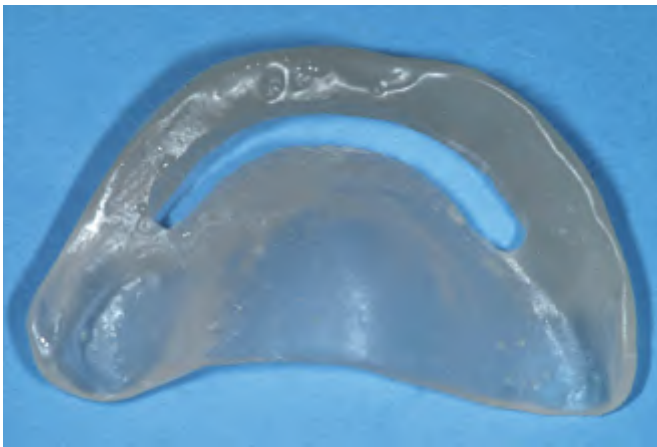


Figure 5.11. Laboratory intaglio view of the processed acrylic resin surgical guide. Since this prosthesis was designed as an overdenture, the implants did not have to be placed congruent with the three-dimensional positions of the planned artificial teeth. Therefore, a window was provided for the surgeon as the guide for implant placement, not specific holes that corresponded to individual, specific teeth.

not considered to be a candidate for immediate occlusal loading. The flap was closed with nonresorbable sutures (Figure 5.14). The patient's immediate maxillary denture was relined with a tissue conditioning material. She was discharged with instructions to take the denture out during nighttime sleep and to eat a soft diet. She was asked to return in 10 days to remove the sutures and reline the maxillary immediate denture.

Due to the relative softness of the bone and the long-term history of smoking (the patient continued to smoke throughout treatment), the surgeon decided to let the implants heal beneath the soft tissues for 5 months.



Figure 5.12. Surgical image after the osteotomies on the right side were initially accomplished. The directional guide indicators are in place and indicated the relative parallelism and the buccal inclination of the implant osteotomies.



Figure 5.13. Panoramic radiograph immediately after six maxillary implants were placed. The implants only achieved insertion torque values of approximately 20 Ncm and were not considered candidates for immediate occlusal loading. The mandibular implants and immediate occlusal loaded prosthesis were placed approximately 14 months prior to this radiograph.



Figure 5.14. Clinical image that demonstrated complete primary closure.

IMPLANT-LEVEL IMPRESSION— LABORATORY PROCEDURES

Implant-level impressions provide clinicians and dental laboratory technicians the opportunity to do abutment selection in the laboratory, directly on the master cast. Angles, soft tissue depths, and interocclusal distances can be more accurately assessed in the laboratory than in a patient's mouth. There are two types of impressions available for use in implant dentistry:

1. Pick-up (open tray) (Figure 5.15)
2. Transfer (closed tray) (Figure 5.16)



Figure 5.15. Pick-up impression copings for 5-mm-diameter implant restorative platforms. The emergence profile diameters for the impression copings are 5, 6, and 7.5 mm (left to right).

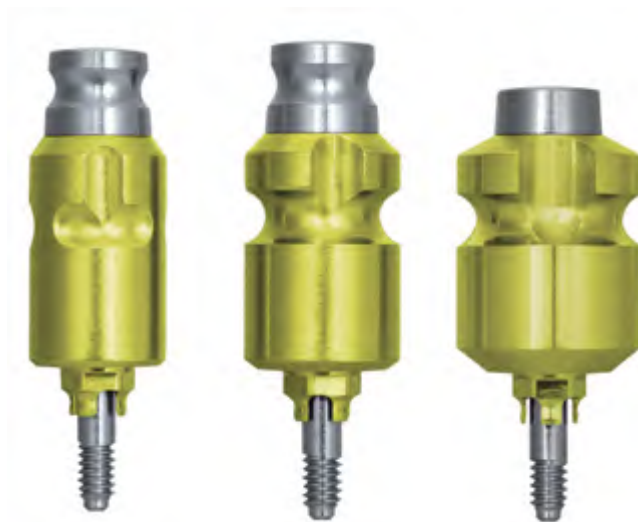


Figure 5.16. Transfer impression copings for 5-mm-diameter implant restorative platforms. The emergence profile diameters for the impression copings are 5, 6, and 7.5 mm (left to right).

Research has not demonstrated consistent, significant differences in accuracy between the two techniques. In a laboratory study, Wenz and Hertrampf (2008) compared the accuracy of impressions made with open- and closed-tray protocols. They found that the distortions in the horizontal plane of the casts obtained from the impression techniques of both groups would probably not affect the clinical fit of implant-retained superstructures. Because of the high variation of deviations (-113 to $+124\mu\text{m}$), they did not recommend the two-step technique. Their method of measuring both impressions and casts provided a better understanding of how the inaccuracies were caused. They also concluded that an exact reproduction of implant positions in a cast obtained from an impression was not possible even under idealized and standardized conditions in the horizontal plane.

In the clinical case illustrated in this chapter, the surgeon chose to use transfer impression copings (TwistLock™, Biomet 3i, Palm Beach Gardens, FL) in a stock plastic impression tray. Transfer impression copings have fewer fingers on the apical ends to decrease the amount of retention relative to the amount of retention present with the fingers for abutments (Figure 5.17). The procedure for preparing the definitive impression prior to pouring a master cast with transfer impression copings is illustrated in Figures 5.18–5.22.

MASTER CAST

Master casts are only as accurate as the impressions they are made from, and the accuracy of impressions has been reported to be variable. Kim and others (2006) performed a laboratory study that measured the variables involved from implant impressions to fabrication of master casts.



Figure 5.17. Illustration of the apical portions of the internal connection for a premachined titanium abutment (left) and an implant impression coping (right). Note that there are six fingers on the abutment connection and four fingers on the impression coping connection.

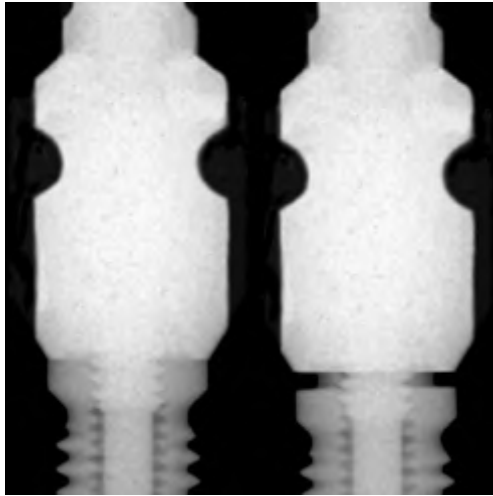


Figure 5.18. Radiographs that demonstrate an impression coping seated onto an implant restorative platform (left), and not seated onto an implant restorative platform (right).

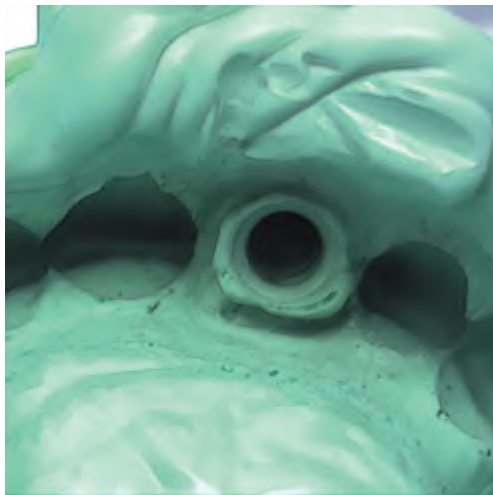


Figure 5.19. Illustration of the intaglio surface of an impression of a transfer impression coping replacing a single tooth in the anterior maxillae. The transfer impression coping is still in the patient's mouth.

Four possible displacements of implant components from a patient model to a definitive cast were assessed to suggest a standard method of comparing the accuracies of implant impression techniques. Two techniques for impressions were assessed: a nonsplinted open-tray technique, and a light-cured resin, splinted open-tray technique.

The average displacements while connecting impression copings and abutment replicas were 31.3 and 30.4 μm , respectively. Less displacement occurred in the non-splinted group compared with the splinted group during

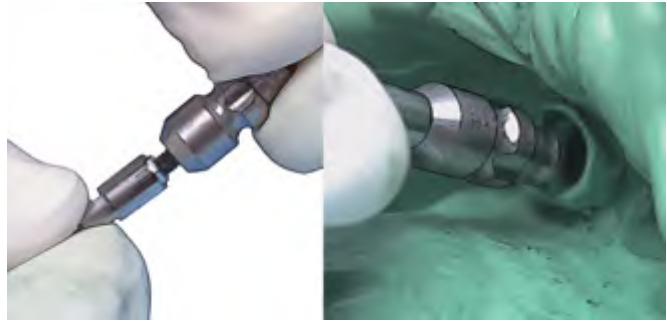


Figure 5.20. Illustration of implant analog (external hex) going to place onto the implant restorative platform of a transfer implant impression coping (left); the analog/impression coping assembly going to place into the intaglio surface of a transfer implant impression (right). The vertical lines of the impression coping go to place consistent with the vertical indentations in the impression. The horizontal concavities of the impression coping lock into the corresponding areas in the impression.

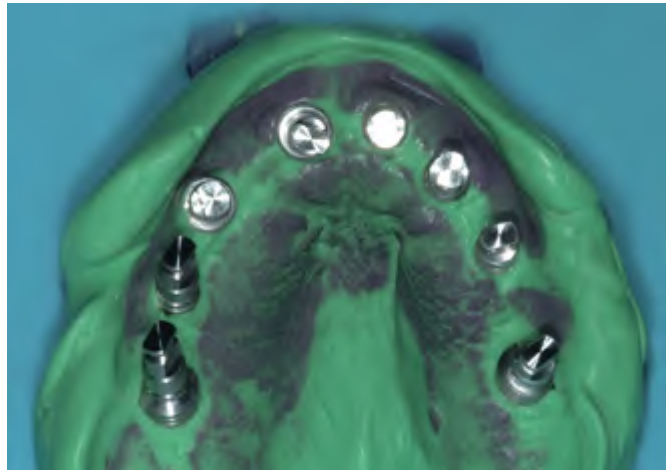


Figure 5.21. Intaglio surface of the definitive impression with transfer impression copings and analogs in place.

impression making ($P = 0.001$), but greater displacement occurred in that group during definitive cast fabrication ($P = 0.015$). They concluded that connecting implant components produced as great a displacement as that resulting solely from an impression or cast fabrication. The nonsplinted impression coping group was more accurate during the making of the impression but less accurate during cast fabrication.

In this clinical case, the impression was poured in type IV dental stone (GC Fujirock® EP, GC America Inc., Alsip, IL) (Figure 5.23; Table 5.3).

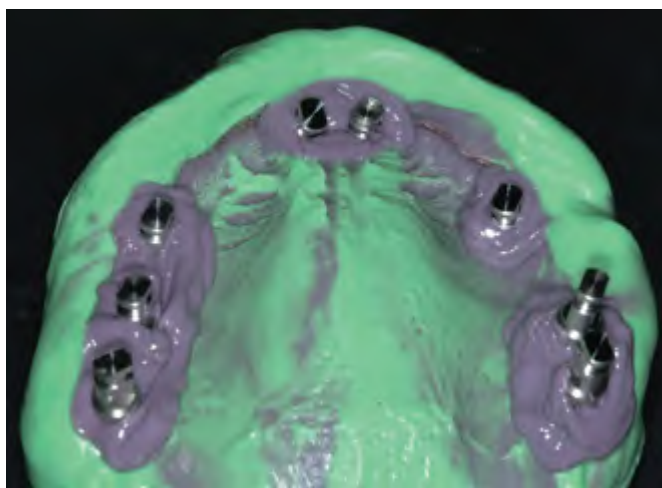


Figure 5.22. Polyether impression material was injected around the impression coping/analog interfaces and allowed to polymerize. This material simulated the peri-implant soft tissues surrounding each implant and could be removed by dental laboratory technicians as needed during fabrication of the implant-retained framework.



Figure 5.23. Laboratory occlusal view of a typical maxillary master cast fabricated with the transfer impression protocol described in the master cast section of this chapter. Removable soft tissue replicas are essential for the CAD/CAM protocol used to fabricate the primary bar used for this patient.

TABLE 5.3. Physical Properties of Fujirock Die Stone

Water-to-powder mixing ratio	20mL/100g
Working time (minimum)	8 minutes
Setting time	12 minutes
Setting expansion	0.08%
Compressive strength at 1 hour	53MPa
Compressive strength at 24 hours	7600psi

RECORD BASES/JAW RELATION RECORDS

The purposes of record bases and occlusion rims are to provide a means to record accurate jaw relation records, hold the teeth in the wax setups for the wax try-ins, and to evaluate the accuracy of the initial jaw relation records. Dentists use record bases and occlusion rims to transmit important clinical information to dental laboratory technicians. Jaw relationships, midlines, high and low lip lines, cuspid lines, amount of horizontal and vertical overlap, and the requisite support for the lips and cheeks can be transferred to the laboratory via articulator mountings and denture setups. The successes of the prosthodontic treatment will, oftentimes, depend on the accuracy of this information.

After the master cast was poured, healing abutments (Figure 5.24) that replicated the healing abutments present in the mouth were placed onto their respective analogs on the maxillary master cast (Figure 5.25).

The maxillary record base was fabricated from light-cured resin and extended into the depths of the buccal vestibules and to the posterior palatal seal. By duplicating the configurations of the healing abutments that were present on the implants intraorally, the maxillary record base became, in essence, a record base with six overdenture abutments (Figure 5.26). Record bases constructed on top of healing abutments provide more accurately fitting record bases than those made on soft tissue and result in more accurate initial jaw relation records. Baseplate wax was added to the maxillary record base to approximate the form of the maxillary arch (Figure 5.27). The height of the wax occlusion rim, measured from the occlusal surface to the highest part of the anterior flange, was arbitrarily established at 22mm. The posterior height of the occlusion rim was established at 8mm, measured from the intaglio surface of the maxillary record base in the area of the second molars (Rudd and Morrow 1980).

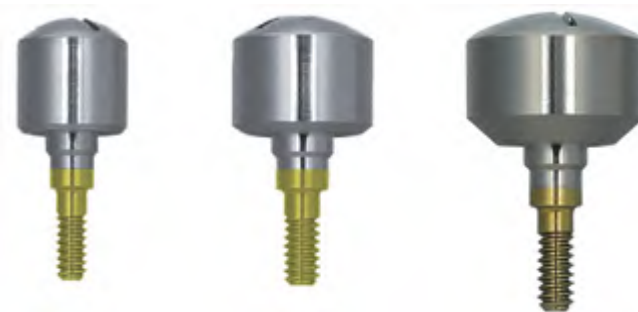


Figure 5.24. These healing abutments were designed for 5-mm implant restorative platforms and measured 5, 6, and 7.5mm in diameter (left to right) (Biomet 3i).



Figure 5.25. Occlusal view of a maxillary master cast with healing abutments in place. The healing abutments corresponded in size and shape to the healing abutments in the mouth. The maxillary record base was made directly on the master cast and healing abutments. Therefore, the healing abutments would not have to be removed at the next two clinical appointments.



Figure 5.26. Laboratory intaglio view of the maxillary record base. The imprints of the seven healing abutments can be seen in the surface of the record base. They lend significant support to the record base during the actual recording of the initial jaw relationship.

The clinical appointment for accurately establishing jaw relationships is sometimes overlooked by clinicians (Phoenix and others 2003). It is absolutely essential that the jaw relation record be accurate relative to occlusal vertical dimension and the centric jaw relationships. The goal in developing an occlusal scheme in implant prosthodontics is to establish and maintain a harmonious relationship with the oral structures/implants and to provide

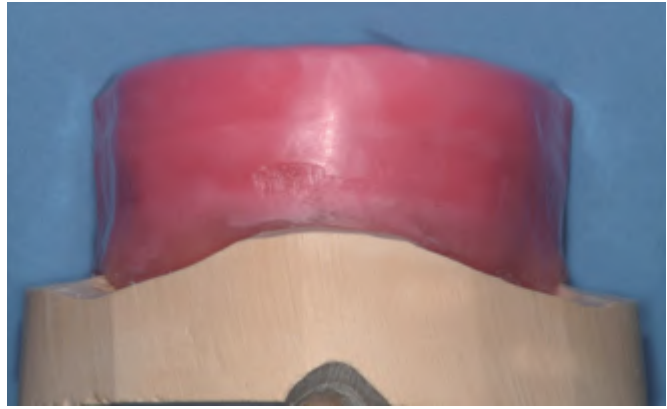


Figure 5.27. Laboratory view of the maxillary record base and occlusion rim. The height of the wax occlusion rim, measured from the occlusal surface to the highest part of the anterior flange, was established at 22 mm. The posterior height of the occlusion rim was established at 8 mm, measured from the intaglio surface of the maxillary record base in the area of the second molars.

mastication that is efficient, with aesthetically acceptable results. Occlusal harmony must be present in centric occlusion/relation and all eccentric positions.

Vertical dimension refers to a vertical measurement of the face and jaws between two arbitrary points: one above and one below the mouth. The vertical dimension of rest (VDR) is defined as the vertical dimension between the two jaws with the patient's head upright and unsupported by a headrest. This dimension is not constant. Sometimes, the recording of the VDR is part of the art of prosthodontics (Rugh and Drago 1981). For convenience, two dots may be placed onto the patient's face: one on the nose and one on the chin. In this case, the patient was asked to wet her lips and slowly close her mouth until her lips touched. This was taken as the VDR (Figure 5.28). Arbitrarily, 3 mm was subtracted from this measurement for the initial VDO.

The maxillary occlusal plane, lip support of the upper lip, and the amount of incisal display at rest, speaking, and smiling were initially established with the maxillary record base and occlusion rim. The initial VDO was established by using gray modeling compound as the anterior stop on the mandibular record base (Kerr Modeling Compound, Kerr Manufacturing, Romulus, MI) (Table 5.4). Once this was established, two posterior stops with the same material were placed on the posterior segments of the mandibular record base, and the actual jaw relation record was made. The midline was marked on the maxillary occlusion rim, and a tooth form and shade were selected (Figure 5.29). The patient was discharged to return for the initial wax try-in.



Figure 5.28. Clinical measurement of the VDR position. In this case, it measured approximately 62 mm. The initial determination of the VDO was arbitrarily 3 mm less than the VDR.



Figure 5.29. Intraoral image of the centric relation record at the predetermined VDO.

TABLE 5.4. Physical and Chemical Properties of Modeling Compound

Boiling point	N/A
Specific gravity ($H_2O = 1$)	>1.0
Vapor pressure (mmHg)	N/A
Melting point	42°C (108°F)
Vapor density (air = 1)	N/A
Solubility in water	Insoluble
Reactivity in water	N/A
Appearance and odor	Multiple colors; waxy

N/A, not applicable.

ARTICULATOR MOUNTING/WAX DENTURES/ VERIFICATION INDEX

Jaw relation records obtained by the dentist are used to orient the casts for mounting in an articulator. In some instances, facebow records may be used for mounting



Figure 5.30. Laboratory image of maxillary and mandibular casts mounted in centric occlusion in a semiadjustable articulator.

TABLE 5.5. Physical Properties of Whip Mix Mounting Stone (Whip Mix Corp., Louisville, KY)

Water/powder ratio	26 mL/100 g
Working time	2–3 minutes
Setting time	5 minutes
Setting expansion	0.08%
Compressive strength, wet (1 hour)	4600 psi (32 MPa)
Compressive strength, dry (48 hours)	8500 psi (59 MPa)

maxillary casts. After a maxillary cast has been mounted, the mandibular cast is oriented to it with an interocclusal record and mounted as well. Casts may also be mounted without facebow records. With this protocol, the casts are positioned in the articulator arbitrarily and attached to the upper and lower members of the articulator with dental stone. Mounting stone is preferable to dental stone or plaster of paris due to its lower setting expansion (Table 5.5).

In this case, the casts were mounted arbitrarily in the articulator with the occlusal plane horizontal, the maxillary midline centered, and the casts in the middle of a semi-adjustable articulator (Figure 5.30).

Denture teeth may be made from porcelain, acrylic resin, composite resin, and resin/metal combinations. All of the different types of teeth have advantages and disadvantages. The authors prefer to use acrylic resin denture teeth because of their versatility, availability, and aesthetics. Anterior teeth may be selected consistent with the patient's



Figure 5.31. The denture teeth were arranged in a Class I occlusal relationship. Twenty-degree posterior teeth were used.

natural teeth, or they may be changed consistent with the patient's wishes. This holds true for both shades and molds. In complete denture prosthodontics, the authors prefer to let patients select their own shades. Mold selection is generally based on two factors. Perhaps the more important factor is related to the space that has been created by tooth loss. In edentulous cases, it is important to remember that the artificial teeth need to be placed where the natural teeth used to be, not in relation to the present shape of the residual ridge.

Under some circumstances patients may wish to change their basic tooth shape and ask the dentist for assistance. There are numerous techniques available to accomplish this. Readers are referred to textbooks on complete denture prosthodontics for further information.

The second factor in mold selection is the overall shape of the teeth. Teeth are generally divided into four basic forms: square, tapering, square-tapering, and ovoid. Tooth shapes may be correlated with facial forms. Clinicians generally use their own experiences to select teeth appropriate for a given patient.

In this case, the teeth were set consistent with the contours of the maxillary occlusion rim. Twenty-degree teeth were used in the posterior segments. These teeth were set for optimal centric contacts and group function occlusion in right and left working movements (Figure 5.31). The teeth were set on the record bases for the wax try-in.

Metal frameworks in implant overdentures require dental laboratory technicians to know where the teeth of the prostheses will be prior to fabrication; therefore, the frameworks in this case were designed after the patient approved the aesthetics of the wax try-in.



Figure 5.32. A verification index was made with autopolymerizing acrylic resin, luted to nonhexed temporary cylinders, and allowed to set for at least 24 hours prior to sectioning.



Figure 5.33. Clinical image of the verification index in individual segments, in place in the mouth. Space existed between each of the sections.

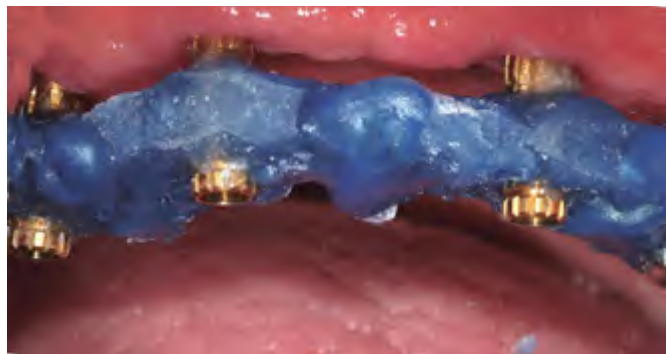


Figure 5.34. Autopolymerizing acrylic resin was used to lute the segments together and allowed to completely polymerize (15 minutes).

Another key element in this protocol for CAD/CAM frameworks is the need to verify the analog positions within the master cast. A verification index was used for this purpose (Figures 5.32–5.35). Autopolymerizing acrylic resin or light-cured resin (Figure 5.36) may be used in fabricating



Figure 5.35. Laboratory image that illustrates the verification index fits passively onto the lab analogs with only one screw in the left distal implant analog. This step was repeated on the other side. There should be no movement between the index cylinders and the implant analogs. Once a cast passes the one-screw test on both distal abutments, clinicians and dental laboratory technicians can assume that the master cast is accurate and has been verified regarding accurate replication of implant placement.



Figure 5.36. Intraoral occlusal image of a verification index made with light-cured resin. This verification index passed the one-screw test without sectioning.

verification indexes. If there is a discrepancy and the verification index does not fit, clinicians are directed to section the index until all of the segments achieve a passive fit. The segments would be related together, and the materials would be cured or polymerized.

There is a great deal of controversy regarding the accuracy of impressions and verification indexes and the impact of ill-fitting implant frameworks on the long-term success of implants. Jemt and Book (1996) studied implant

prosthesis misfit and radiographic bone loss for 14 patients (seven maxillary, seven mandibular prostheses) prospectively for 1 year and retrospectively for the last 4 years of the 5-year period after second-stage surgery. Their results demonstrated that none of the prostheses presented a completely passive fit on the implants in vivo. Furthermore, similar misfits were found in both groups, indicating that the implants seemed to be stable and did not move even after several years in function. The mean centerpoint misfit was $111\mu\text{m}$ ($\text{SD} = 59$) and $91\mu\text{m}$ ($\text{SD} = 51$) for the 1- and 5-year groups respectively, with a range of $275\mu\text{m}$. The corresponding mean marginal bone loss was 0.5 and 0.2mm for the two follow-up groups. They noted no statistical correlations ($P > 0.05$) between change of marginal bone levels and different degrees of prosthesis misfit in either group. Jemt and Book (1996) speculated that implants may possess a certain biological tolerance for ill-fitting frameworks.

The wax try-in was completed uneventfully, and the case was now ready for design and construction of the CAD/CAM framework.

OVERVIEW OF THE DESIGN/CONSTRUCTION OF CAD/CAM FRAMEWORKS

CAD/CAM implant frameworks have demonstrated more accurate fits between frameworks and implants than cast frameworks (Jemt 1996; Jemt and Book 1996). Ortorp and others (1999) investigated the accuracy of frameworks made with computer numeric controlled (CNC)-milled frameworks ($n = 20$) and those made with conventional type IV gold alloy ($n = 5$). They reported that the CNC frameworks demonstrated a statistically better fit and precision of fabrication compared with conventional castings ($P < 0.05$) and concluded that it was possible to fabricate CNC implant-retained frameworks with high precision and repeatability. The previous study related to a copy milled-type bar where a pattern is created by a dental laboratory technician with the appropriate contours required in the framework. The pattern is scanned and a milling unit mills the framework as designed in the pattern.

Another type of CAD/CAM machining involves designing frameworks totally with computer software and having the digital data transmitted to a computerized milling unit for milling.

The maxillary framework illustrated in this case was fabricated using the copy milling process and is called a CAM StructSURE® Precision Copy Milled Bar. This particular technology is available through Biomet 3i. Copy milling allows dental laboratory technicians the opportunity to create their own unique bar designs in a resin pattern that will be scanned by Biomet 3i. A one-piece titanium alloy

replica of the design provided by the technician will be milled to fit the master cast. The mandibular framework in this case was designed entirely by computer and milled from the approved design.

This CAD/CAM protocol has numerous advantages for commercial dental laboratories:

1. CAD/CAM precision
2. No capital investment required
3. No waxing and casting (not applicable for copy milling)
4. No soldering or welding
5. Designed by dental laboratory technicians
6. Can be used with multiple implant systems
7. Increased strength when compared with conventional castings
8. Can be made on implant restorative platforms or abutments

CAM StructSURE Precision Milled Bars are indicated in the following clinical situations:

1. Implant or abutment restorative platforms
2. Implant overdentures, fixed hybrid, and fixed partial denture implant prostheses with 2–10 implants
3. Parallel and divergent implants up to 30 degrees
4. Four millimeters or less of soft tissue depth
5. At least 7 mm of interocclusal distance
6. Multiple implants with a minimum of 2 mm of space between implants

The CAM StructSURE Precision Copy Milled Bar planned for this case was a primary bar to support/retain a maxillary overdenture. These CAD/CAM bars are also available for use as frameworks in hybrid fixed prostheses, Hader and Dolder bars, or for frameworks for fixed partial dentures. The CAD/CAM bars are made from commercially pure titanium or titanium alloy. In order to fabricate a bar, Biomet 3i requires the following items:

1. Verified soft tissue master cast
2. Verification index
3. Signed work order (Figure 5.37)
4. Wax denture

For CAD-designed frameworks, once Biomet 3i receives the above items, a Patient Specific Restoration (PSR) technician scans the wax denture and master cast with the

implant analogs in place and designs the framework in CAD. The CAD design is e-mailed to the commercial dental laboratory for design approval. Once the design is approved, the CAD design is transferred to a milling machine for fabrication of the bar. If the design was not approved, the dental laboratory technician in the commercial dental laboratory would telephone the PSR technician in Florida and discuss the changes and/or concerns. A new CAD design would be developed and e-mailed back to the dental laboratory technician for approval.

The accuracy of CAM StructSURE Precision Milled Bars is undergoing laboratory investigations at three universities in Minnesota, Wisconsin, and Florida. An abstract was presented at the Academy of Osseointegration, Boston, MA, in February 2008 (Drago 2008). In this pilot laboratory study, one CAD/CAM and one cast metal framework were fabricated from an edentulous maxillary model with a conventional prosthodontic protocol. The protocol involved polyvinyl siloxane impressions and acrylic resin verification indexes to make the master casts. The original model, with implant analogs, was scanned with a laser optical scanner; the CAD/CAM framework was designed and milled from a solid blank of titanium alloy. The pattern for the cast framework was made with nonhexed abutments and autopolymerizing acrylic resin, and cast in gold/palladium alloy. The implant/abutment interfaces of both frameworks were scanned, and the images were virtually overlaid onto the scanned implants of the original patient model in a process called lofting. Via an electronic, virtual one-screw test protocol on a distal implant, volumes were calculated between the implant/abutment interfaces for the other four implant/abutments. The measurements were repeated with the electronic, virtual one-screw test on the contralateral implant/abutment interface.

The CAD/CAM framework fit was significantly more precise than the cast framework fit (volumetric differences: 8.4591 mm³ left; 1.2781 mm³ right) (Figures 5.38 and 5.39).

The results of this pilot laboratory study suggested that the CAD/CAM bar fit the implants more accurately and with less distortion than did the one-piece cast framework made with similar design parameters. Additional laboratory research is indicated to evaluate the degree of misfits obtained with additional cast and CAD/CAM frameworks.

Maxillary Copy Milled Bar

The master cast was fabricated per the above protocol. Wax dentures were also fabricated and tried in. The patient was pleased with the aesthetic results, and the prosthodontist verified the jaw relationships, midline, lip support, and incisal display during speaking, smiling, and at rest (Figures 5.40 and 5.41).



Work Order

*1. Account Information (Please Print)

* Lab Name: _____
BIOMET 3i Account#: _____
* Contact: _____
* Phone: _____
Fax: _____
* Email: _____
* Patient ID: _____
* Ship To: _____

Bill TO: _____

Doctor Name (Optional): _____

*Indicates Required Field

2. Preparing Your Case For Shipment

IMPORTANT:
• **Only** use new implant analogs.
• Please **do not** send the articulator.

Please include **only** the following items:
☐ Copy of the completed work order
☐ Verified/accurate soft-tissue cast
☐ Resin pattern if CopyMill bar is desired
☐ Verified wax try-in, disinfected
☐ Disinfected intraorally verified index, (optional)

**3. Structure Type

Overdentures	Fixed Solutions	Combination
☐ Hader	☐ Hybrid #1	☐ Hader anterior, Primary distal
☐ Dolder® U shape Macro → 2.2mm	☐ Hybrid #2	☐ Hader anterior, Dolder distal
☐ Dolder Eggshape Macro → 2.2mm	☐ Wrap Around	☐ Dolder anterior, Primary distal
☐ Primary ____ Taper	☐ CopyMill (Resin Pattern Enclosed)	☐ Dolder anterior, Hader distal
☐ Canada Bar		☐ Primary anterior, Hader distal
		☐ Primary anterior, Dolder distal

** See Compatibility Chart in CAM StructSURE Manual (ART868)

**4. Case Information

Tooth Position	Implant Brand**	Implant System	Implant Platform Diameter		Abutment Type
				or	
				or	
				or	
				or	
				or	
				or	
				or	
				or	
				or	
				or	

** See Compatibility Chart in CAM StructSURE Manual (ART868)

5. Design Instructions

- † See design matrix in CAM StructSURE Manual (ART868)
- † Maximum implant divergence is 30°
- † Minimum distance between implants is 2mm

Distal Extensions

Patients Left

- ☐ To 2nd bicuspid
- ☐ To 1st molar
- ☐ To 2nd molar
- ☐ Specify in mm = ____ mm

Patients Right

- ☐ To 2nd bicuspid
- ☐ To 1st molar
- ☐ To 2nd molar
- ☐ Specify in mm = ____ mm

Space Between Tissue And Bar

Distance

- ☐ Close as possible
- ☐ Specify in mm = ____ mm

Shape

- ☐ Follow tissue contour
- ☐ Straight

Bar Height

- ☐ Specify in mm = ____ mm (min. height 2.5 mm)

Tap Areas For Attachments

Occlusal Taps

- ☐ LOCATOR®
- ☐ TSB Ball
- ☐ Ceka® M3
- ☐ 1.4 mm 0.3 Tap for GSH30
- ☐ 2.0 mm 0.4 Tap for UNIHT

Vestibular Taps

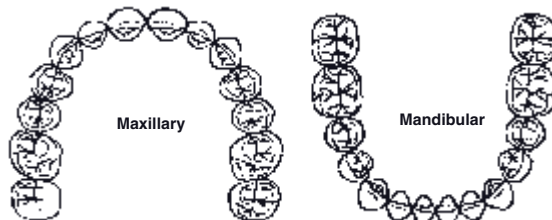
- ☐ Swiss-loc
- ☐ Low Passive
- ☐ 1.5 mm no tap drill only
- ☐ VKS

☐ Design bar according to the drawings below

● = Implant Position

■ = Clip Placement

▲ = Attachment



6. Special Instructions

☐ Please see back or attached page.

7. BIOMET 3i Screw Ordering

☐ I would not like to order screws at this time.

Certain® Abutment screws

Gold-Tite® Hexed Large Diameter (ILRGHG)

Titanium Hexed Large Diameter (ILRGHT)

External Hex Abutment Screws

Gold-Tite Square (UNISG)

Gold-Tite Hexed (UNIHG)

Titanium Hexed (UNIHT)

Laboratory Square Try-in Screw - 5 pack (UNITS)

Retaining Screws

Gold-Tite, 2 mm(H) (GSH20)

Gold-Tite, 3 mm(H) (GSH30)

Gold-Tite, 7 mm(H) (GSH70)

Waxing Screws

Certain - Implant Level Waxing Screw, 16 mm (IWSU30)

External Hex - Implant Level Waxing Screw, 15 mm (WSU30)

Abutment Level Waxing Screw, 10 mm (WSK10)

Abutment Level Waxing Screw, 15 mm (WSK15)

8. Attachment Ordering

LOCATOR Bar Attachment Kit (LOAB)

Hader Clip Gold (ORCG1)

Hader Clip Plastic (ORCY1)

9. Certification

I certify that the analog positions on the cast and the wax try-in have been verified for accuracy and the stated information is correct. All items that have contacted the oral environment have been disinfected. This form authorizes BIOMET 3i to fabricate the CAM StructSURE Precision Milled Bar using and consistent with the information provided on this work order.

Technician Signature _____

Date _____

Job # _____

Issued By _____



CAM StructSURE, Certain and Gold-Tite are registered trademarks of BIOMET 3i, Inc. BIOMET is a registered trademark and BIOMET 3i and design are trademarks of BIOMET, Inc. Dolder is a registered trademark of Prof. Eugen Dolder. Ceka is a registered trademark of Ceka Corporation. LOCATOR is a registered trademark of Zest Anchors, Inc. ©2007 BIOMET 3i, Inc. All rights reserved.



ART880

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Figure 5.37. This is a full-page copy of the work order to be completed by a dental laboratory technician and sent to Biomet 3i's Architech PSR Center.

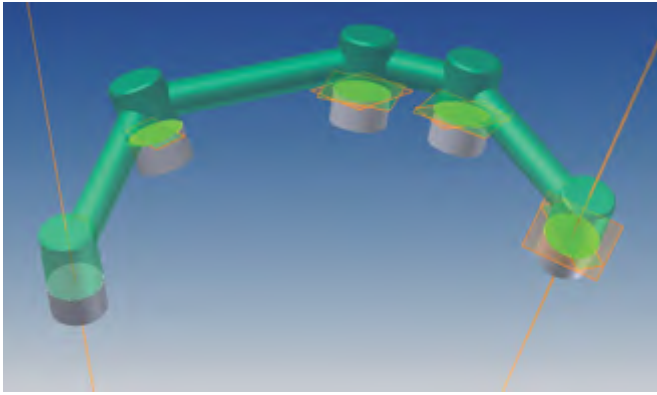


Figure 5.38. Illustration of the virtual one-screw test for a cast bar. The screw was virtually placed on the left distal implant and the volumetric differences were measured (virtually) between the implant restorative platforms of the abutments in the bar and the implants.

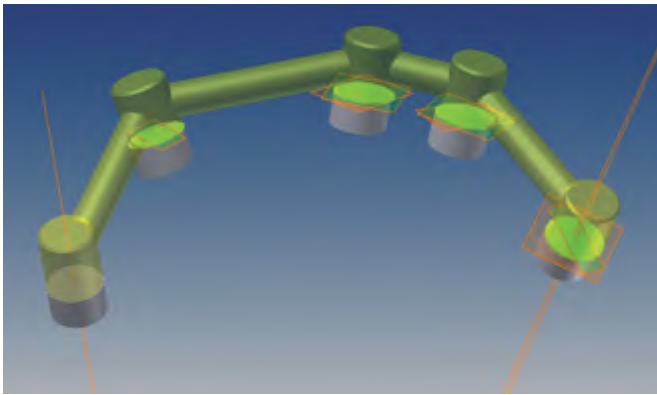


Figure 5.39. Illustration of the virtual one-screw test for the CAD/CAM bar (CAM StructSURE Precision Milled Bar). The screw was virtually placed on the left distal implant and the volumetric differences were measured (virtually) between the implant restorative platforms of the abutments in the bar and the implants.

A resin pattern was fabricated consistent with the design considerations for a maxillary primary bar:

1. One-degree taper vertically on each wall (total occlusal convergence was 2 degrees)
2. Adequate thickness for rigidity and strength
3. Optimal location for the attachments
4. Appropriate clearance between the apical portion of the bar and the soft tissue
5. Optimal emergence profiles

Nonhexed titanium implant temporary cylinders (CC300, Biomet 3i) were placed on the analogs and screwed into place with try-in screws (IUNITS, Biomet 3i).



Figure 5.40. Clinical image of the patient smiling with the waxed dentures at the try-in appointment.

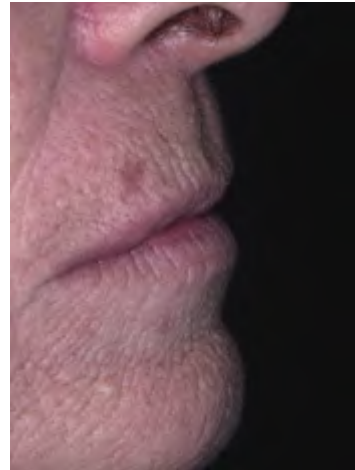


Figure 5.41. Clinical profile image of the waxed dentures with the patient at rest. The patient was pleased with lip contours at rest.

Autopolymerizing acrylic resin was used to splint the cylinders together. The contours were modified per the above parameters. The bar was milled with a 1-degree taper on each vertical wall (2 degrees total) (Figures 5.42 and 5.43).

The bar was designed to be used with two anterior Bredent 2.2 VKS-OC stud-head screws (XPdent Corp., Miami, FL) that were to be screwed directly into the tapped sites prepared by the Architech PSR Department after the bar was milled (Figure 5.44). VKS-SG attachments are available in two sizes: 2.2 and 1.7 mm in diameter. They have been designed for use in many different clinical and laboratory situations and may be placed in various locations: on the buccal, lingual, distal, or mesial surfaces of bars or



Figure 5.42. Laboratory occlusal image of the resin pattern for construction of the maxillary copy milled bar.



Figure 5.43. Laboratory facial image of the resin pattern for the maxillary copy milled bar on the cast, with a plastic mold of the wax denture in place. The plastic mold gave the dental laboratory technician the locations of the teeth in the prosthesis and allowed for adequate thickness of the bar and secondary casting, and adequate prosthetic space for development of the prosthesis.



Figure 5.44. Anterior view of the copy milled bar after the holes were tapped into the planned locations of the anterior attachments.

TABLE 5.6. Dimensions of SwissLoc NG Attachments Used in This Case

Description	Dimensions	Order Number
SwissLoc NG 6.0mm	6.8-mm length	
Housing	3.4 mm	
Plunger	1.5 mm	89-600060
Tools		
SwissLoc NG	Screwdriver	89-600015
SwissLoc NG	Processing jig (2)	89-600015
SwissLoc NG	1.5-mm drill	74-600615

Note: The SwissLoc 7.5 and 6.0mm can be reduced to a minimum of 4.5mm if necessary. To shorten, pull the head of the plunger to the fully extended out position. Cut off the housing and the plunger *together* with a diamond disk. Lengths are premarked at 5.5 and 6.5mm. These SwissLoc attachments may be shortened to any length between 7.5 and 4.5mm.

crowns. There are 10 different levels of retention available for use with these attachments. Another distinct advantage is that the female, plastic portions of the attachments are replaceable chairside and do not require patients to be without their prostheses for an extended period of time.

The posterior attachments were 6-mm SwissLoc attachments (Attachments International, Burlingame, CA) (Table 5.6). The precision machined SwissLoc NG Next Generation is an extracoronal locking pin/plunger attachment designed to prevent lift-off, a common problem that has been reported with bar overdentures. The SwissLoc NG minimizes occlusal cantilever forces from lifting the prosthesis anterior/posterior or buccal/lingual. The design incorporates positive in and out positions, which prevent the attachment from disengaging unintentionally. The second author designed the location of all of the above attachments.

The framework was scanned and transferred into the CAD software. The copy milled bar CAD design matched the contours of the acrylic resin pattern (Figure 5.45). After the milling was completed, the bar was finished, polished, and returned to the commercial dental laboratory (Figures 5.46 and 5.47).

Electroformed Bar Sleeves

Electroforming is the term used where a three-dimensional metal structure is formed by an electric current. In dentistry, this process may be used to fabricate a pure gold substructure for crowns, fixed partial dentures (FPDs), and bars. Electroforming was first introduced by Luigi Galvani



Figure 5.45. The image of a copy milled bar in the CAD software.



Figure 5.46. Laboratory occlusal view of the maxillary primary bar as received from Biomet 3i. The contours and dimensions corresponded exactly to those developed in the resin pattern. The anterior attachments are visible on the labial surface of the bar.



Figure 5.47. Laboratory labial view of the maxillary primary CAD/CAM bar with the anterior attachments in place.

more than 200 years ago; it was first introduced for dental use in the early 1960s (Dietrich 2001). Electroforming technology is used in dentistry with remarkable accuracy to create extremely thin (0.2mm), yellow gold-colored substrates of uniform thickness for enhanced aesthetics and exceptional marginal integrity (Vence 1997).

Electroforming eliminates casting techniques with the lost wax protocol and the disadvantages associated with them, specifically contamination and inconsistencies associated with nonhomogenous castings. Compared with cast gold, electroformed gold is much harder and electroformed restorations demonstrate improved fit, are biocompatible, and provide solid bases for the definitive restorations (Setz and others 1989; Dietrich 2001; Dolger and others 2001).

In this case, an Aesthetic Galvanotechnik Crown (AGC®, Wieland Dental Systems, Milford, CT) protocol was used. The CAD/CAM bar was thoroughly cleaned of polishing materials and other residues with ultrasonic cleaning. The bar had been milled with a 1-degree taper (2 degrees total); all undercuts were eliminated. The bar was screwed directly onto the master cast, and the screw access openings, interdental spaces, and the areas apical to the bar were blocked out. The cast and bar were duplicated with a silicone duplicating material (Dubli Gum, Wieland Dental + Technik GmbH & Co. KG, Pforzheim, Germany) (Figure 5.48). The impression was poured in Super Hard Plaster (Wieland Dental + Technik GmbH & Co. KG) (Table 5.7).

AGC Conductive Silver Lacquer was applied to the internal surface of the mold in an even, thin layer up to the end of the bar impression and was allowed to dry for 60 minutes. The lacquer was then applied in a wide connection between the bar impression and the contact rods. The impression was placed into the AGC Spider electroforming machine, and the electroformed bar was made.

Tertiary Casting

Once the copy milled and the electroformed bars were completed, a tertiary casting was required for strength within the denture base. The tertiary casting was necessary to maintain the attachments in consistent positions and to provide the requisite strength for the maxillary overdenture.

Two layers of die spacer were applied to the electroformed bar, and a wax pattern with beads for acrylic resin retention was developed. This bar was cast with new base metal alloy ingots (Wiron® 99, Bego USA, Lincoln, RI) (Figures 5.49–5.52; Table 5.8). In a study conducted by Al-Hiyasat and Dramani (2005) where the effects of recasting alloys and element release was measured, Wiron 99 and another



Figure 5.48. Impression of a maxillary primary bar prior to pouring a cast for construction of the electroformed bar (top). Stone cast of the maxillary bar created from the above impression (bottom).

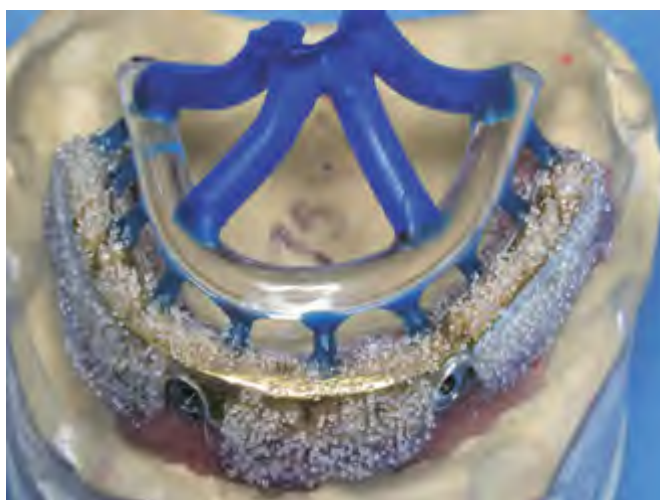


Figure 5.49. Laboratory labial/occlusal view of the wax pattern for the tertiary bar just prior to casting. Small beads were sprinkled onto the wax pattern for additional acrylic resin retention.

TABLE 5.7. Characteristics of Super Hard Plaster

Mixing ratio	100g power/20mL water
Working time	7 minutes
Setting time	12 minutes
Expansion	0.1 vol %
Compressive strength	60MPa



Figure 5.50. Laboratory intaglio view of the electroformed bar cemented into the tertiary bar. The electroformed bar provided an extremely intimate fit between the superstructure of the maxillary overdenture and the primary bar.



Figure 5.51. Laboratory occlusal view of the tertiary casting. The beads were to be used for macroscopic acrylic resin retention. The casting was also silicoated and opaqued. The silicoating provided additional retention between the secondary bar and the acrylic resin of the denture base.

base metal alloy demonstrated the least cytotoxicity. However, Tripuraneni and Namburi (2008) reported that considering the elevated genotoxicity of Ni-Cr alloy in their reused state, the practice of reusing Ni-Cr alloys just for economic reasons should be discouraged.

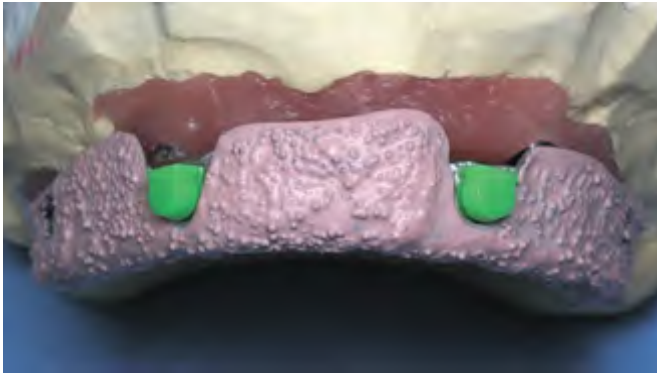


Figure 5.52. Laboratory facial view of the secondary and tertiary bars in place over the primary bar. The plastic anterior attachments were in place.

TABLE 5.8. Wiron 99 Alloy Composition and Working Characteristics

Element	Percentage
Ni	65
Cr	22
Mo	9.5
Nb	1
Si	1
Fe	0.5
Ce	0.5
C (max)	0.02
Casting temperature	1420°C

The tertiary casting was cemented to the electroformed bar with CEKA Site cement (CEKA N.V., Antwerp, Belgium).

Mandibular CAM StructSURE Precision Milled Bar

The master cast was fabricated per the above protocol. Wax dentures were also fabricated and tried in. The patient was pleased with the aesthetic results, and the prosthodontist verified the jaw relationships, midline, lip support, and incisal display during speaking, smiling, and at rest (see Figures 5.38 and 5.39).

The mandibular framework was designed for use as the framework for a screw-retained hybrid prosthesis. The following are contraindications for using a CAM StructSURE Precision Milled Bar:

1. Cases with more than 10 implants
2. Greater than 30 degrees divergence between implants
3. Less than 2mm between implants

4. Less than 7 mm of interarch space
5. More than 4 mm of soft tissue depth around any implant

A separate work order (see Figure 5.37) was completed for the mandibular framework. The cast and wax denture were scanned, and the data were transferred into the CAD software. Initially, this system was developed so that the CAD designers sent individual JPEG images of the design to the dental laboratory technician via e-mail (Figures 5.53–5.55). The dental laboratory technician would review



Figure 5.53. Occlusal surface of the CAD design for the mandibular framework. The location and arrangement of the denture teeth can also be visualized.



Figure 5.54. Lingual surfaces of the CAD design for the mandibular framework. This two-dimensional image provided visual references in terms of thickness of the proposed framework, the location of the artificial teeth, and the amount of space available for the acrylic resin denture base.

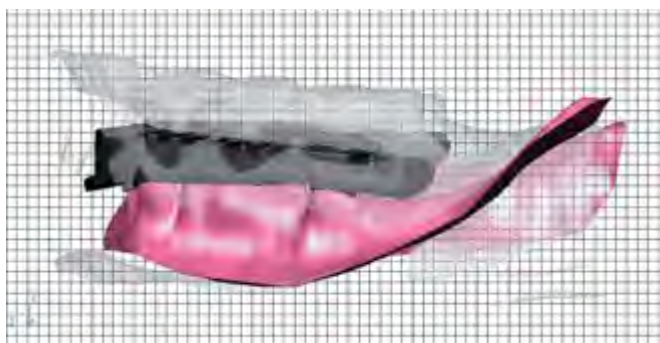


Figure 5.55. Left buccal surface of the CAD design for the mandibular framework.



Figure 5.56. New, revised CAD design for the mandibular framework. The left posterior segment was shortened, relative to the original design in Figure 5.53.

the images and note any design modifications that were deemed necessary. The technician would then call the CAD designer and discuss the changes. The CAD designer would then make the changes and e-mail the JPEG images of the new designs to the dental laboratory technician for additional review. This process would continue until the design was agreed upon by the laboratory technician and the CAD designer. In this case, the cantilevered segment distal to the left posterior implant was shortened (Figure 5.56).

At the present time (June 2008), CAD designs are available for review via eDrawing. The eDrawings are available with a free software download (www.eDrawingsViewer.com/download). Laboratory technicians will receive an e-mail from the Architech PSR Department with instructions for the download of the above software. Technicians will review the procedures and agree to the terms and



Figure 5.57. Original screen image (via e-mail) that will now appear on the computer monitor when a dental laboratory technician opens an eDrawing file from the Architech PSR Department.

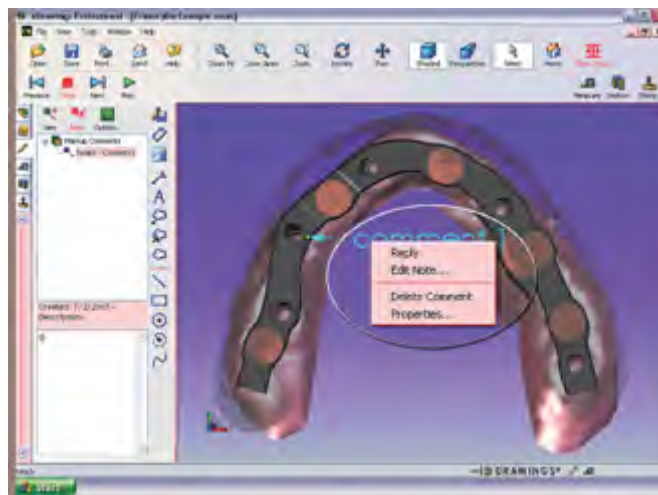


Figure 5.58. Image that corresponds to a window where comments may be typed directly onto the screen regarding design changes that the laboratory technician wants to modify from the original design.

conditions. These steps are necessary only for the initial software download.

Technicians will click to open the image file. The image viewing tools are located on the tool bar (Figure 5.57). The image may be rotated, zoomed in and out, but it cannot be altered by the viewer. The viewer can always go back to the original image by clicking "Home." The viewer can select the "text with leader" tool in the markup section to type comments onto the area of the image where changes are desired (Figure 5.58). Once the design changes have been made, the technician will select the "Save As" option under "File," which saves the drawing with the comments.



Figure 5.59. Laboratory occlusal view of the mandibular CAM StructSURE Precision Milled Bar, as received from Biomet 3i, on the mandibular master cast. Note the presence of the gold abutment screws in the screw access openings. Definitive gold-coated abutment screws should never be used by commercial dental laboratories for any laboratory procedure (left inset). Try-in screws should be used instead (right inset). This framework was silicoated and opaqued prior to setting the denture teeth prior to try-in (top inset).

The image and comments will then be e-mailed back to the Architech PSR Department for review and processing.

The framework in this case was milled and returned to the commercial dental laboratory (Figure 5.59). Try-in screws should always be used in the laboratory as the 24-karat gold coating of the clinical abutment screws is quite fragile and will wear away. This negates the benefits associated with the thin layer of gold that acts as a lubricant during application of the clinical application of preload to the screws (Drago 2003).

With the initial use of CAD/CAM technology for implant frameworks, the first author (C.D.) originally scheduled framework try-ins for frameworks made with the CAD/CAM protocol described above. However, over time and in the absence of misfitting frameworks received from Biomet 3i, the author changed the scheduling protocol and eliminated separate framework try-in appointments. With the elimination of the above appointments, he also ordered that the frameworks be silicoated and opaqued and had the denture teeth set onto the frameworks once they were returned from Biomet 3i to his commercial dental laboratory.

Silicoating

In prosthodontics, the attachment of a resin matrix to a metal framework may pose significant short- and long-term

difficulties. The major problems are related to the strength of this attachment and the space available for restorative materials. Low bond strength between the resin and metal framework may result in microleakage, discoloration, or breakage. Minimal space available for metal frameworks, resin matrix, and denture teeth may result in compromised tooth placement and a less than ideal bond between the prosthetic materials. Clinically, limited space and low bond strength may result in unacceptable aesthetics, a need for excessive adjustment of the occlusion, or breakage of any of the materials. To minimize clinical problems, it is therefore imperative to optimize the strength of the resin attachment to the metal framework and ensure that there is sufficient room for materials.

Until recently, the attachments of resin matrices to metal frameworks have been obtained through mechanical retention between the resin and the frameworks. Mechanical retention can be achieved using latticework, mesh, beads, and various posts (Henderson and Steffel 1981). Alternative attachment mechanisms are now available, however, including micromechanical and chemical attachment systems.

Micromechanical attachment can be accomplished using sandblasting, electrochemical etching, and chemical etching (Adept Institute 1991). Chemical attachment may be achieved using adhesive cements, porous metal coatings, silicoating (Hansson 1989) and the Kevloc system. These alternative attachment systems can be used either as an addition to or in place of conventional macromechanical retention.

There are numerous advantages to the chemical resin/metal attachment systems:

1. Increased bond strength between the resin and metal
2. Decreased microleakage at the resin/metal interface
3. Reduction in metal impingement on the space needed for the placement of denture base resin and teeth
4. Improved aesthetics because the metal frameworks have been opaqued and increased thickness of resin

For the fixed removable implant prosthesis fabricated in this case, there were areas where there was a limited amount of space available for the denture base resin, denture teeth, and frameworks. We wanted to avoid construction of a bulky metal framework and maximize the retention of the processed acrylic resin denture base to the frameworks. Macromechanical retention was incorporated into the tertiary framework in the form of beads that were cast into the framework. SiliClean and SiliLink were the materials used in the Silicoater MD oven (Heraeus Kulzer, Armonk, NY).



Figure 5.60. Laboratory labial views of wax dentures with silicone impression material in place on the labial and buccal surfaces of the denture teeth. Retentive grooves were cut into the silicone to provide physical retention for the plaster indexes (PolySil™ Firm Putty, Accurate Set, Inc., Newark, NJ). This facilitated replication of the denture setups from the wax dentures to the frameworks. Silicone was used as the impression material because it could easily be removed from any undercuts. Maxillary denture (top); mandibular denture (bottom).

DENTURE SETUP ON CAD/CAM FRAMEWORKS

The denture teeth had already been selected by the restorative dentist and confirmed by the patient at the initial wax try-in appointment. The teeth that were originally selected by the patient at the first jaw relation record appointment were transferred from the original setup to the maxillary and mandibular frameworks (Figures 5.60–5.66).

CLINICAL TRY-IN APPOINTMENT

The following goals were established for this clinical appointment:

1. Metal try-in (one-screw test)
2. Verification of the jaw relation records
 - a. New interocclusal record if necessary
3. Aesthetic approval



Figure 5.61. Laboratory lingual view of the mandibular denture teeth within the plaster matrix after removal from the cast.



Figure 5.62. Laboratory lingual view of the mandibular plaster/silicone index with the denture teeth attached, in place on the master cast. The space between the teeth and the cast/analogs will be occupied by the framework and denture base.



Figure 5.63. Laboratory palatal view of the maxillary plaster/silicone index with the denture teeth attached, in place on the master cast. The metal frameworks were also in place. Note the amount of available space between the denture teeth and the tertiary bar for the denture base acrylic resin.



Figure 5.64. Laboratory view of the left posterior segments with the maxillary primary bar in place, opposed by the mandibular waxed prosthesis. Note the significant amount of horizontal overlap between the labial surfaces of the mandibular anterior denture teeth and the location of the maxillary primary bar and implants. The distance was greater than 10 mm. This distance validated the use of the maxillary overdenture with a labial flange to provide optimal lip support for the patient's aesthetic needs while giving the patient access to the bar and implants for oral hygiene and plaque removal. All polishing procedures regarding the implant frameworks were accomplished with polishing protectors in place (PPSA3, Biomet 3i).



Figure 5.65. Laboratory anterior view of completed implant prosthesis denture setups in the articulator. The maxillary midline was centered, consistent with the patient's facial midline. The interdental spaces in the mandibular anterior segment were requested by the patient.



Figure 5.66. Laboratory view of the left posterior segments of the maxillary and mandibular wax dentures and frameworks. The maxillary premolars were not in optimal positions but were satisfactory for the authors to proceed with the clinical try-in appointment.

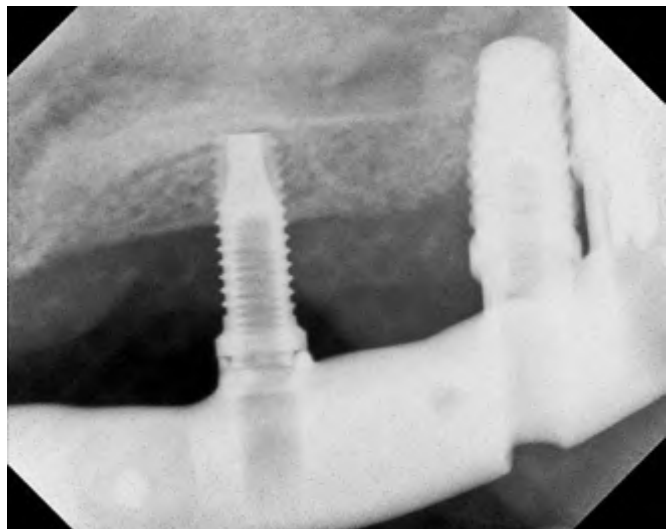


Figure 5.67. Radiographic image that demonstrated a passive fit of the maxillary framework. The abutment screw was in place in the second implant (right to left). The framework was noted to fit without a radiolucency visible between the framework and the implant restorative platform of the right distal implant.

All of the interim implant components were removed and the frameworks/wax dentures were tried in individually, with individual abutment screws in various positions within the frameworks. Radiographs were taken of the implant/framework interfaces opposite the abutment screw. Frameworks are said to be passively fitting if there are no spaces between the implant restorative platforms and the frameworks. Passive fits were demonstrated for both of the frameworks (Figures 5.67 and 5.68).

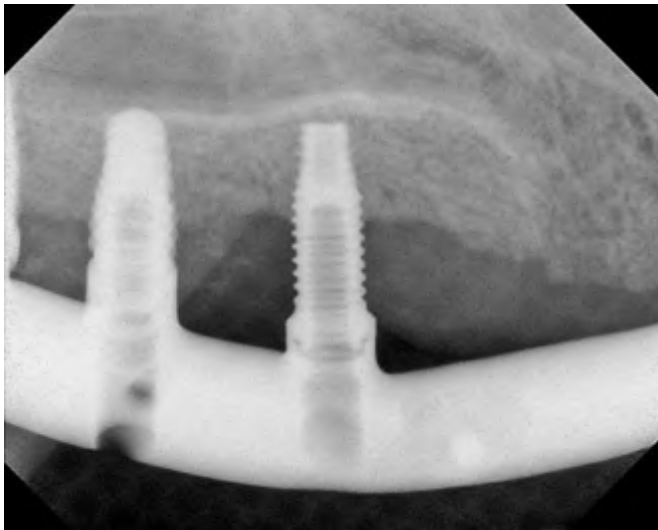


Figure 5.68. Another radiographic image that also demonstrated a passive fit of the maxillary framework to the maxillary implants. The abutment screw was in place in an implant not in the image (distal left implant). The framework was noted to fit without a radiolucency visible between the framework and the implant restorative platform of the two right implants in the image.



Figure 5.69. Clinical image with the mandibular wax implant prosthesis and the maxillary primary bar in place. The mandibular occlusal plane was horizontal and in satisfactory position relative to the retromolar pads bilaterally.

The clinical appointment continued. The mandibular wax prosthesis went to place (Figure 5.69). The occlusal plane was verified as being horizontal and otherwise in satisfactory position. The maxillary wax prosthesis also went to place, and the centric jaw relation record was verified (Figures 5.70 and 5.71). The VDO, lip support, and incisal display during speaking, smiling, and at rest were satisfactory, and the patient offered no suggestions (Figures



Figure 5.70. Clinical image of the wax implant prostheses right posterior segments, with the patient in centric occlusion. This position demonstrated maximum intercuspation and satisfactory tooth arrangements.



Figure 5.71. Clinical image of the wax implant prostheses left posterior segments, with the patient in centric occlusion. This position demonstrated maximum intercuspation and, with the exception of the maxillary left second premolar, satisfactory tooth arrangements.

5.72 and 5.73). She wished for the prostheses to be processed.

PROCESSING

There are numerous methods and materials to process acrylic resin in prosthodontics. Turck and others (1992) performed a laboratory study and used the Michigan Computer Graphics Coordinate Measurement System (MCGCMS) to determine the dimensional accuracy of dentures processed by three different techniques: conventional heat compression, microwave, and visible-light activation. Standardized dentures were fabricated from casts made in a silicone mold. All casts were dupli-



Figure 5.72. Clinical image of the patient smiling with both wax implant prostheses in place. The amount of incisal display was consistent with the patient's desires and age.

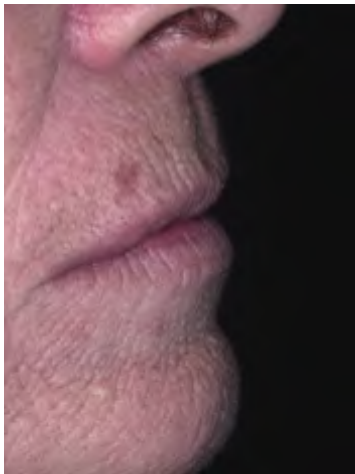


Figure 5.73. Clinical image of the patient in profile, at rest, with the lips just touching and both wax implant prostheses in place. The lips had appropriate fullness.

cated with hydrocolloid and 42 dentures were made (14 dentures for each technique). The MCGCMS measured 22 points on two frontal planes to compare the master casts with the dentures. The results showed no significant difference in overall dimensional accuracy. At specific sites, however, the visible-light-activated technique produced significantly more flange distortion than did either the conventional or microwave techniques.

Injection molding protocols for processing acrylic resin dentures are relatively new. Acrylic resin complete dentures undergo dimensional changes during polymeriza-

tion. Techniques with injection molding and polymerization and microwave polymerization are reported to reduce these changes and thereby improve clinical fit. Keenan and others (2003) performed a laboratory study and compared differences in dimensional changes of simulated maxillary complete dentures during polymerization and storage in water after injection molding and conventional polymerization, or microwave polymerization against a control of conventionally packed and polymerized simulated maxillary complete dentures.

They prepared 40 identical maxillary denture bases in dental wax with anatomical teeth. They were invested, and the wax was eliminated from the molds. Ten specimens each were randomly assigned to one of four groups. Group 1 was compression molded and conventionally polymerized; group 2 was injection molded and conventionally polymerized; group 3 was injection molded and conventionally polymerized; and group 4 was injection molded and microwave polymerized. Intermolar width and changes in VDO were determined after polymerization and after storage in water for 28 days. Measurements in triplicate were made between points scribed on the second molar teeth with a traveling microscope (accurate to 0.005mm). VDO was measured between points scribed on the upper and lower members of an articulator by use of an internal micrometer (accurate to 0.05mm). Data were analyzed, and they found polymerization contractions (intermolar widths) for each group.

The microwave specimens had greater shrinkage than conventionally polymerized specimens, but there were no significant differences between the groups. All injection methods had less postpolymerization increase in VDO than the conventional controls, but only the injection molded group was significantly different ($P < 0.004$). After storage in water for 28 days, all specimens increased in VDO (0.10%–0.16%) from polymerization techniques, but there were no significant differences between groups.

Within the limitations of their study, Keenan and others (2003) found that injection molding resulted in a slightly less increase of VDO than conventional polymerization techniques, the difference being significant for microwave-processed complete dentures compared with the conventional controls.

The wax prostheses were returned to the articulator for final waxing and tooth positions. Definitive waxing involved contouring the wax on the frameworks to a form that reproduced the contours of the original tissues of a dentulous mouth.

The areas directly cervical to the necks of the denture teeth were carved in such a way as to reproduce the gingival



Figure 5.74. Clinical image of a patient that demonstrates the slight roll of the free gingival margins associated with natural teeth. In this instance, the free gingival margins were more exaggerated around the anterior than the posterior teeth.



Figure 5.75. Laboratory image of the wax implant dentures that demonstrated a subtle roll around the necks of the denture teeth, replicating the free gingival margins of the natural dentition.

bulge associated with the free marginal gingival surrounding natural teeth (Figures 5.74 and 5.75). Slight root prominences were developed over the roots of the maxillary central incisors, a root concavity around the roots of the maxillary lateral incisors, and prominent cuspid eminences apical to both of the maxillary cuspids (Figure 5.76).

The dentures were flaked and processed with heat-cured acrylic resin (Lucitone 199® Denture Base Resin, Dentsply International, York, PA) in conventional fashion (Figures 5.77–5.80; Table 5.9).



Figure 5.76. Laboratory image of the wax dentures that demonstrated the root prominences and concavities in the denture bases associated with the anterior and posterior teeth.



Figure 5.77. Laboratory image of the lower half of a brass denture flask with the mandibular wax denture in place, after the first pour of dental stone.

After processing, the dentures were remounted. Little processing error was noted (Figures 5.81 and 5.82). The prostheses were adjusted to have even occlusal contacts throughout the prostheses. Right and left working occlusions were designed for group function occlusion. In protrusive, the anterior teeth discluded the posterior teeth. Balancing contacts were eliminated. The dentures were finished and polished using conventional acrylic resin polishing techniques. All polishing procedures should be accomplished with polishing protectors in place to protect the machined interfaces of the machined restorative plat-



Figure 5.78. Laboratory image of the lower half of a brass denture flask with the maxillary wax denture in place, after the first pour of dental stone.



Figure 5.80. Laboratory image of the lower half of the brass denture flask after the wax was boiled out. The maxillary frameworks were completely exposed and ready for packing with acrylic resin.



Figure 5.79. Laboratory image of the lower half of the brass denture flask after the wax was boiled out. The mandibular framework was completely exposed and ready for packing with acrylic resin.

forms contained within the implant frameworks (Figures 5.83–5.90).

Due to lack of a periodontal ligament, osseointegrated implants, unlike natural teeth, react biomechanically to occlusal forces different from the manner in which natural teeth react. It is possible that dental implants may be more prone to occlusal overloading, which has been regarded as one of the potential causes for peri-implant bone loss

TABLE 5.9. Properties and Recommended Procedures for Lucitone 199 Denture Base Resin

Type and class (according to ADA specification #12)	Type I, Class I
Storage temperature for powder and liquid	60–80°F
Powder-and-liquid ratio	21 g/10mL
Mixing time (time required to wet all particles)	15–30 seconds
Time to reach packing plasticity at 23 ± 1°C	9 ± 2 minutes
Working time	10 ± 4 minutes
Material used to prepare mold	Gypsum
Temperature of mold when packing	Approximately 110°F
Recommended cure time and temperature	
First stage	1–1.5 hours at 163°F
Second stage	0.5 hours at 212°F
Alternate cure time and temperature	9 hours at 163°F
Method of cooling flask, time, and temperature	
First stage	0.5 hours in air at 60–80°F
Second stage	0.25 hours in water at 60–80°F



Figure 5.81. Laboratory image of the right segments of the processed dentures remounted on the articulator after processing. There was minimal change in the VDO after processing.



Figure 5.82. Laboratory image of the left segments of the processed dentures remounted on the articulator after processing. There was minimal change in the VDO after processing.

and failure of implants/implant prostheses. Overloading factors that may compromise implant survival rates include long cantilevers, parafunctional habits, occlusal designs, and defluctive occlusal contacts. Hence, it is important to control implant occlusion within physiological and physical limits and provide optimal implant loads to ensure long-term implant survival. Kim and others (2005) discussed the importance of implant occlusion for implant survival and



Figure 5.83. Laboratory image of the occlusal surface of the mandibular processed, screw-retained prosthesis. The screw access openings were refined to accept the clinical driver (PHD03, Biomet 3i) required to tighten the abutment screws. Note that the clinical abutment screws are in place, retaining the prosthesis to the analogs. This is not the optimal use of these screws (IUNIHG, Biomet 3i; left inset). Try-in screws (IUNITS, Biomet 3i; right inset) are the more appropriate choice.



Figure 5.84. The apical surface of the mandibular implant prosthesis. The machined implant restorative platforms were maintained during the polishing process with polishing protectors.

provided clinical guidelines of optimal implant occlusion and possible solutions managing complications related to implant occlusion. It must be emphasized that, currently, there is no evidence-based, implant-specific concept of occlusion. Future studies in this area are needed to clarify the relationship between occlusion and long-term implant survival and prosthetic success.



Figure 5.85. Anterior laboratory view of the polished mandibular prosthesis in place on the master cast. The apical position of the facial finish line and the opaque material allowed precise finishing of the acrylic resin without show through of the framework.

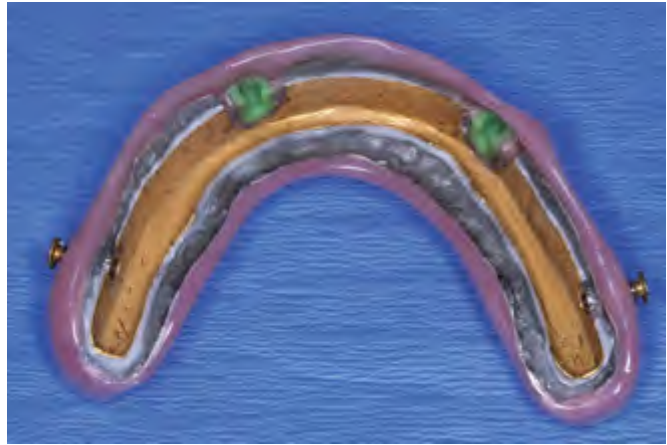


Figure 5.87. Intaglio surface of the completed maxillary overdenture with the secondary casting inside the denture base. Both of the posterior attachments are in the lateral, nonengaged positions. Acrylic resin flowed into a mild undercut apical to the right anterior attachment. The excess resin was removed from the internal surface of the denture base prior to the clinical try-in.



Figure 5.86. Laboratory image of the occlusal surface of the maxillary overdenture in place on the primary bar (not visualized).

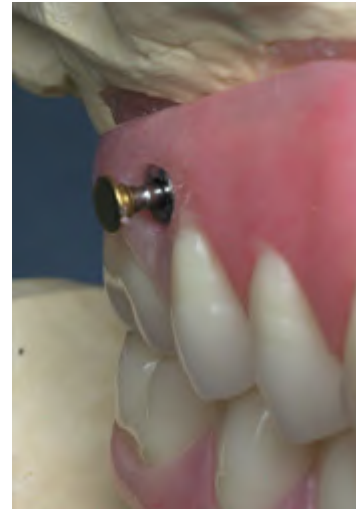


Figure 5.88. Lateral image of the right maxillary posterior attachment in the nonengaged position.

INSERTION

The patient returned for the insertion appointment. All of the healing abutments were removed, and the mandibular prosthesis went to place without incident (Figure 5.91). Clinical abutment screws were used (IUNIHG, Biomet 3i)

and torqued to 20Ncm with a torque driver. The screw heads inside the screw access openings were initially blocked out with cotton pellets and then restored with light-cured composite resin (Figure 5.92). The anterior access openings were restored with denture-base-colored resin; the posterior access openings were restored with tooth-colored composite resin.

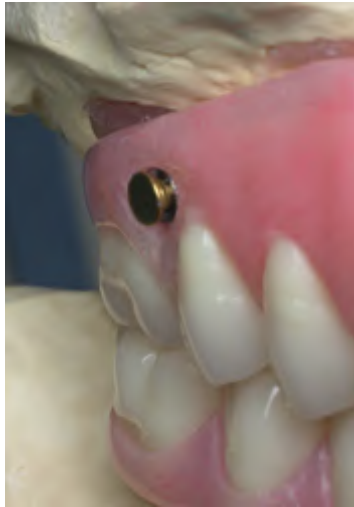


Figure 5.89. Lateral image of the right maxillary posterior attachment in the engaged position. When the prosthesis was fully seated, the buccal end of the attachment is not quite flush with the acrylic resin of the denture base. This space allowed the patient to insert a fingernail medial to the knob, push the attachment buccal, and deactivate the attachment. The process would be repeated on the contralateral side.



Figure 5.90. The completed, polished prostheses in place on the master casts. They were ready to be shipped to the prosthodontic office for insertion.

The maxillary primary bar went to place directly to the implants with the same clinical abutment screws described above and torqued to 20 Ncm with a torque driver (Figure 5.93). The maxillary overdenture prosthesis went to place. Acrylic resin undercuts were identified and removed prior to seating (Figure 5.94). Both of the posterior attachments went completely to place; the anterior attachments were



Figure 5.91. Clinical occlusal view of the mandibular implant prosthesis in place. Clinical, gold-coated abutment screws (IUNIHG) were used to retain the prosthesis directly to the implants. The abutment screws were torqued to 20 Ncm with a torque driver.



Figure 5.92. Clinical occlusal view of the mandibular implant prosthesis in place after the screw access openings were restored with light-cured composite resin.

also engaged and the prosthesis was stable. No occlusal adjustments were required at this clinical appointment, indicating to the clinicians the high degree of precision that was maintained throughout this complex treatment.

The patient was extremely satisfied with the aesthetic results and was even able to bite into a pear immediately post insertion without dislodging either prosthesis (Figures 5.95–5.98).

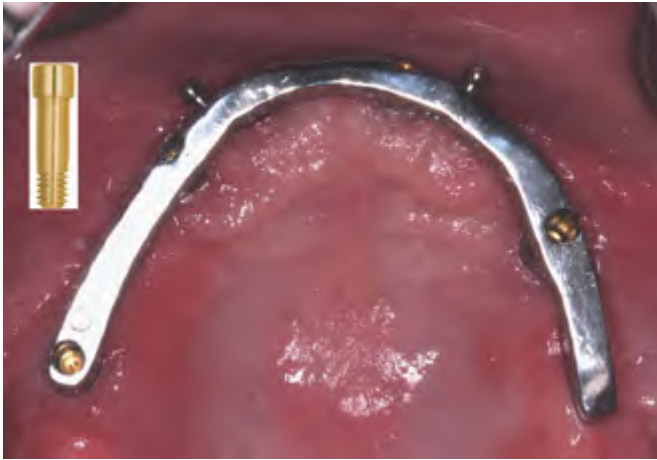


Figure 5.93. Clinical occlusal view of the maxillary primary bar in place. Clinical, gold-coated abutments screws (IUNIHG; inset) were used to retain the prosthesis directly to the implants. The abutment screws were torqued to 20 Ncm with a torque driver.



Figure 5.94. Clinical occlusal view with the maxillary overdenture in place. The posterior attachments were in the active positions. Tissue blanching was not seen.



Figure 5.95. Clinical right buccal view of the prostheses in place, with the patient in centric occlusion.



Figure 5.96. Clinical left buccal view of the prostheses in place, with the patient in centric occlusion.



Figure 5.97. Clinical extraoral image of the patient with a full smile. Note the normal, anatomical contours of the denture base, as well as the asymmetric arrangement of the teeth. Overall, this gave an extremely natural appearance of the implant prostheses.



Figure 5.98. Clinical extraoral image of the patient biting into a pear immediately after insertion of the implant prostheses. This patient continued to enjoy normal function with little need to return for postinsertion adjustments.

The following clinicians and dental laboratory technicians were responsible for the treatments illustrated in this chapter:

Implant Surgeon: Dr. Robert del Castillo, Miami Lakes, FL

Prosthodontist: Dr. Carl Drago, Jupiter, FL

Dental Laboratory Technicians: Thomas Peterson, CDT, MDT; Eunice Park, Robin Devine, Alan Kalivas, MDT, North Shore Dental Laboratories, Lynn, MA

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Chapter 6: Computed Tomography (CT)-Guided Surgery/ Immediate Occlusal Loading with a Full-Arch Prosthesis in the Edentulous Mandible

IMMEDIATE OCCLUSAL LOADING

Immediate occlusal loading has been defined by Testori and others (2003) as placing at least five implants into edentulous mandibles, splinting them together with a rigid fixed prosthesis and placing them into full, functional occlusion on the day of implant placement. Their preliminary study reported the results of 15 patients, with 103 implants that were placed into function within 36 hours of implant placement. The patients were followed for up to 48 months postoperatively, and they reported cumulative survival rates (CSR) of 98.9% for the implants and 100% for the immediate prostheses. Testori and others (2003) concluded that rehabilitation of edentulous mandibles with immediately loaded hybrid prostheses, supported by five to six implants, may represent a viable alternative treatment to the classic delayed loading protocols (Figures 6.1–6.3).

TILTED IMPLANTS

Capelli and others (2007) reported on the results of a study to assess the treatment outcomes of immediately loaded full-arch screw-retained prostheses with distal extensions supported by both upright and tilted implants for the rehabilitation of edentulous jaws and to compare the outcomes of upright versus tilted implants. At four study centers, 342 implants (Osseotite NT®, Biomet 3i, Palm Beach Gardens, FL) were consecutively placed into 65 patients (96 implants/24 mandibles; 246 implants/41 maxillae). The two distal implants in all jaws were tilted 25–35 degrees. Provisional full-arch restorations (titanium frameworks and acrylic resin teeth) were delivered within 48 hours of surgery and immediately loaded with full functional occlusion. The final prostheses were delivered 3 months post implant and prosthesis placement (Figure 6.4).

Capelli and others (2007) reported that three implants failed during the first year and another two implants failed within 18 months of loading in the edentulous maxillae. The CSR for the maxillary implants was 97.59%, with up to 40 months of follow-up. No implant failures were recorded for the mandible. The prosthetic survival rate was 100%. Marginal bone loss around upright and tilted implants was similar. Patients reported that they were satisfied with their aesthetics, phonetics, and function. Capelli and others

(2007) concluded that the preliminary results suggested that immediate occlusal loading of edentulous maxillae and mandibles with hybrid prostheses supported by six or four implants, respectively, may represent a viable treatment alternative for treating edentulous patients without significantly more invasive surgeries such as sinus lifts or block bone grafts. The clinical results indicated that immediately loaded tilted implants may achieve the same outcome as upright implants in both jaws. Other researchers have reported similar high CSRs for immediate occlusal loading in both edentulous jaws (Bergkvist and others 2005; Maló and others 2005; Tealdo and others 2008).

DIAGNOSTIC IMAGING

Diagnostic imaging plays a significant role in developing comprehensive diagnoses and treatment plans. Per Kircos and Misch (2005), the decision when to image and which imaging modalities to use may be organized into three phases.

Phase I has been identified as preprosthetic implant imaging and includes all necessary surgical and prosthetic information to determine the quantity, quality, and location of available bone in the proposed implant sites, the relationship of critical structures to the prospective implant sites, and the presence or absence of disease in the proposed implant sites (Figures 6.5–6.7).

Kircos and Misch (2005) identified five objectives for preprosthetic imaging:

1. Identification of disease
2. Determination of bone quality
3. Determination of bone quantity
4. Determination of ideal implant position(s)
5. Determination of ideal implant orientation(s)

Phase II was identified as surgical and interventional implant imaging and is used to evaluate the surgical sites during and immediately after surgery. It also assists in optimal placement of the implants and restorative components relative to the planned position of the teeth in the proposed prostheses.



Figure 6.1. Preoperative panoramic radiograph of a patient who was to be treated with extractions of the remaining mandibular teeth, alveolectomy, immediate placement of five interforaminal mandibular implants, and fabrication/insertion of a fixed, mandibular implant-retained prosthesis with full occlusal loading on the day of surgery.

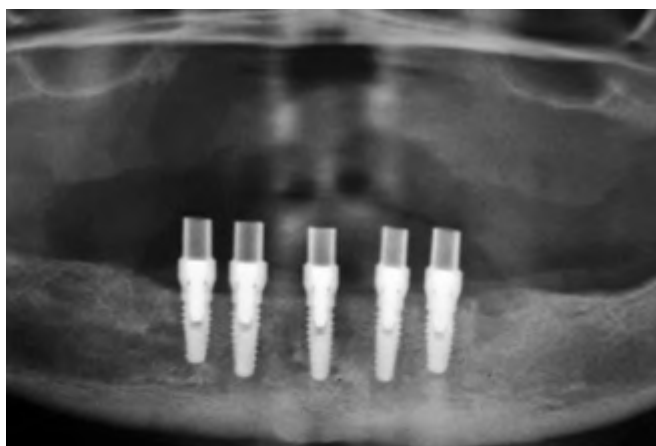


Figure 6.2. Postoperative panoramic radiograph of the patient in Figure 6.1 immediately post implant placement and abutment connection.



Figure 6.3. Postoperative clinical image of the patient in Figures 6.1 and 6.2 just prior to discharge after the above surgical and prosthetic treatment was accomplished.



Figure 6.4. Postoperative panoramic radiograph of a patient treated with tilted posterior implants and immediately loaded with full-arch restorations.

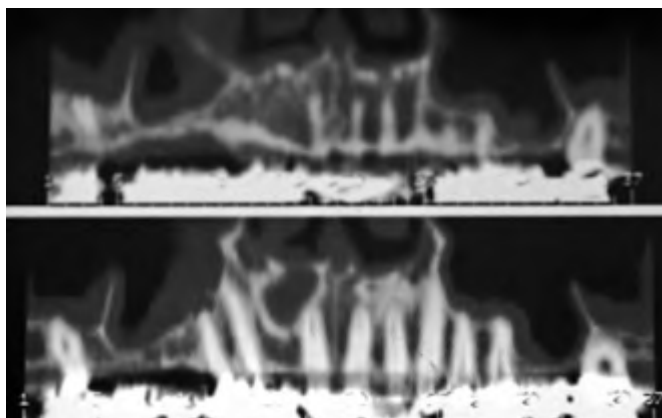


Figure 6.5. Preoperative CT scans (panoramic views). These two images were taken at different planes, several millimeters apart. The most significant finding was the severe pneumatization noted in the right maxillary sinus.

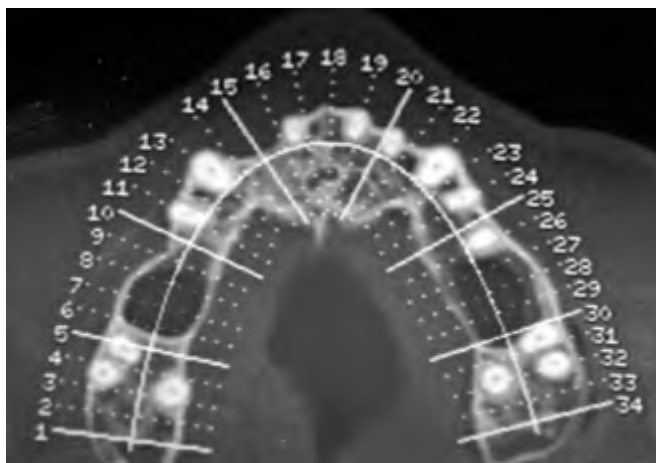


Figure 6.6. Preoperative CT scan (maxillary occlusal view). This slice was taken apical to the cemento-enamel junctions (CEJs) of the maxillary molars. The three roots of the molars were clearly visible. The radiolucencies between the molars and the first premolar on the patient's right side, and the second premolar on the patient's left side indicated the vertical depth of the sinus pneumatization.

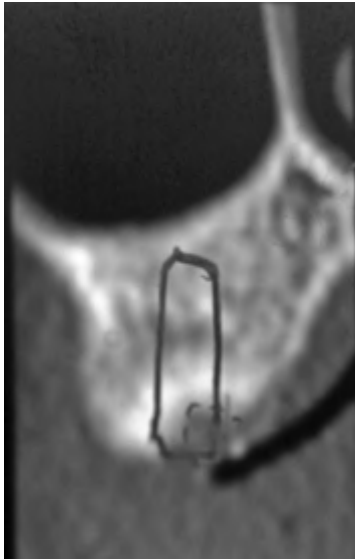


Figure 6.7. This lateral slice of the CT study was taken in the area of the missing maxillary right first molar after maturation of the bone graft into the right maxillary sinus. A simulated 5-mm-diameter implant was drawn to simulate ideal implant placement. Note the bulk of bone that was added to the floor of the right maxillary sinus compared with the minimal amount of bone present in the preoperative CT scans in Figure 6.5.

Phase III was identified as postprosthetic implant imaging and commences immediately after implant and prosthesis placement. Phase III continues as long as the implants remain in the jaws. The objectives of this phase are to evaluate the long-term maintenance of implant rigid fixation and function, including crestal bone levels around each implant and to evaluate the overall conditions of the implant/prosthetic complex (Figure 6.8).

The bulk of preprosthetic imaging usually takes place with panoramic radiography. Panoramic radiographs are made as a curved plane tomographic study that identifies the mandible, maxillae, and usually at least the lower half of the maxillary sinuses in a single film. Panoramic radiographs provide for qualitative data and are not considered to be diagnostic for exact replication of physical data because panoramic radiography produces images of sections of the jaws of variable thickness and magnification (Figure 6.9).

Kircos (1990) identified the advantages of panoramic radiography as follows:

1. Anatomical landmarks are easily identified
2. Initial assessment of the vertical bone heights
3. Panoramic radiographs are generally convenient for most dental practitioners to perform



Figure 6.8. This is a digital periapical image of a three-unit implant-retained prosthesis in place, immediately after cementation. It served as the baseline Phase III radiograph that is necessary to follow up on postinsertion bone levels and overall health of the implant/restoration complex.



Figure 6.9. Typical example of a traditional preoperative panoramic radiograph that was taken as part of the preprosthetic implant imaging Phase I workup for this patient.

4. Gross, macroscopic anatomy of the jaws and related pathology can be evaluated

Tomography is a generic term that was adopted by the International Commission on Radiological Units and Measurements (1962) to describe all forms of body section radiography (DeLuca 2007). Body section radiography is a radiological technique that enables visualization of a section of a body by blurring regions of the body immediately above and below the section of interest. For dental patients, high-quality complex motion tomography

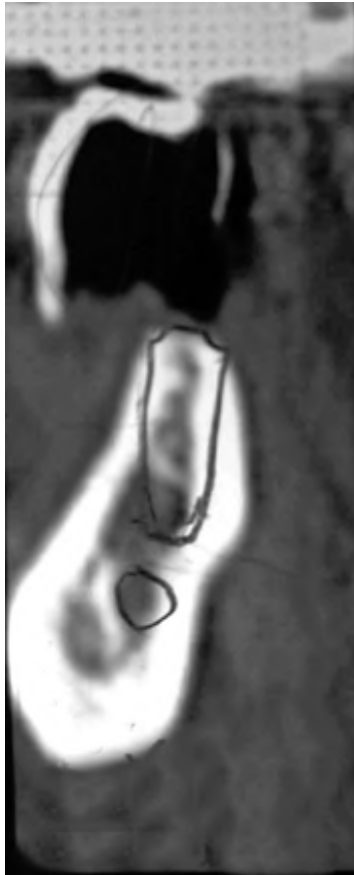


Figure 6.10. This particular lateral slice of the CT scan identified the precise location of the inferior alveolar canal and the midportion of the planned implant restoration. Tentatively, a 5×11.5 -mm implant was selected for this particular edentulous area. CT scans have the requisite accuracy for surgeons to feel confident that their osteotomy preparations and implant placement will not encroach on important anatomical structures.

demonstrates the alveolus, and with magnification taken into consideration, enables quantification of the anatomy of the alveolus and related structures (Eckerdal and Kvint 1986). This type of radiographic study enables clinicians to determine the spatial relationship between the critical structures and the implant sites (Figure 6.10). Ideally, tomographic sections of 1–2mm allow evaluation of the proposed implant sites and permit visualization of the three-dimensional appearance of the alveolus and other anatomical structures (Figure 6.11).

COMPUTED TOMOGRAPHY (CT)

CT is a digital imaging modality that creates tomographic sections where the layers are not blurred with artifacts from adjacent anatomical structures. CT allows differentiation between the hard and soft tissues, thus allowing accurate

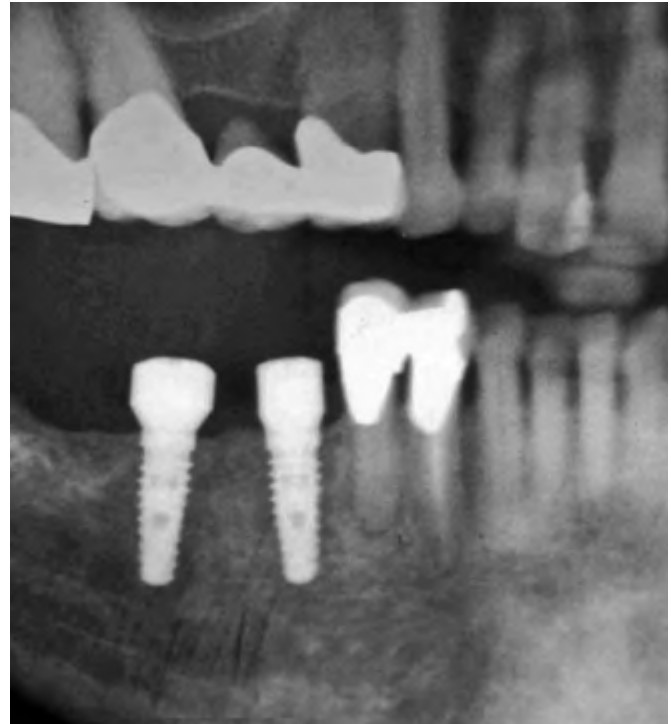


Figure 6.11. This quadrant section of a panoramic radiograph was taken immediately post implant placement. The implants were placed, with the benefit of CT treatment planning, without violating the inferior alveolar canal and/or the mental nerve.

images of teeth, lamina dura, periodontal ligament spaces, cortical bone, and alveolar bone. CT produces axial images perpendicular to the long axis of the anatomy being examined. CT images are, by definition, three-dimensional images, with thicknesses corresponding to the slice spacing of the particular imaging protocol. Each individual element of a CT image is called a voxel and has a value (Hounsfield units) that describes the density of the CT image. Each voxel contains 12bits of data and ranges from -1000 (air) to $+3000$ (enamel/dental materials) Hounsfield units. CT scanners are generally calibrated at a Hounsfield value of 0 for water. The CT density scale is quantitative and meaningful in identifying and differentiating structures and tissues.

The efficacy of CT for imaging the maxillofacial regions has been documented since its introduction in the 1980s (Helms and others 1982). The differences in tissue densities can be used to differentiate tissues within each image and can also characterize bone quality according to Lekholm and Zarb (1985), Shahlaie and others (2003), and Lee and others (2007) (Figures 6.12 and 6.13).

The improved diagnostic capabilities of CT, especially in regard to treatment planning for dental implants, has been



Figure 6.12. Illustration of Type I through Type IV bone.

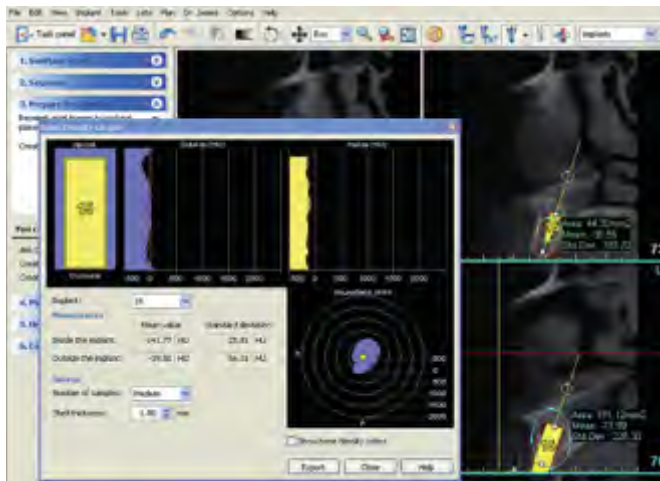


Figure 6.13. This is a screen shot of a software program (SimPlant 12.0) used for presurgical treatment planning. The Hounsfield units within the walls of the osteotomy averaged -141.77 and -39.50 outside the osteotomy. The low values were consistent with the anatomical location (posterior maxillae) and Type IV bone.

well known for quite some time (Eckerdal and Kvint 1986; Stella and Tharanon 1990). However, access to CT scanners by dentists was limited, as was the interpretation of the scans by radiologists. The logistics of reformatting the CT scans was laborious, and then the information was shipped to the referring dental practitioner for use, who may or may not have known how to interpret the studies. These difficulties led to the development of CT scanning for dental purposes. The new scans were identified as Dentascans (Kircos and Misch 2005).

Kircos and Misch (2005) identified the limitations of Dentascans:

1. Images may not be true size and require compensation for magnification
2. Determination of bone quality required the use of the imaging computer

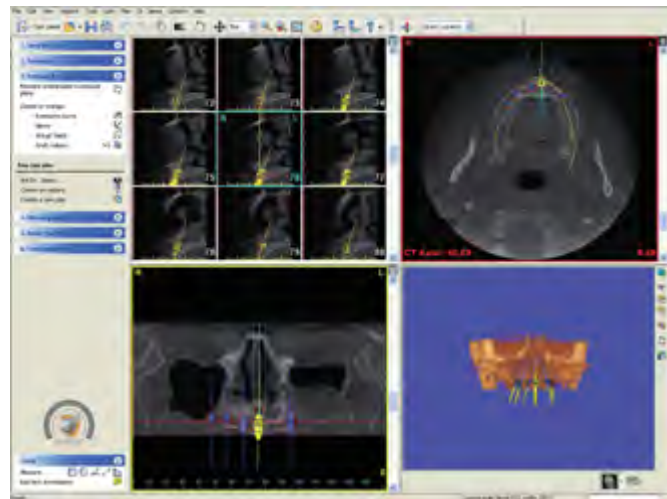


Figure 6.14. This is a screen shot of the same software program noted in Figure 6.13. The views can be changed depending on the particular stage in the treatment planning process for a given patient. Different-sized implants, from multiple implant manufacturers, are available in the implant library. The implants can be pasted into a given cross-sectional image and manipulated in terms of their three-dimensional orientation for optimal positioning within the alveolus and in regard to the locations of the teeth.

3. Hard copy Dentascan images included only a limited range of the diagnostic gray scale of the study
4. The tilt of the patient's head during the examination was critical to maintain since the each cross-sectional image must be perpendicular to the axial imaging plane

INTERACTIVE CT (ICT)

ICT has addressed many of the limitations associated with CT (Van Steenberghe 2005). The digital scanning information can now be transferred to a disk from the imaging center. With the appropriate software program, clinicians can now develop treatment plans on their personal computers (Figure 6.14). Per Parel and Triplett (2004), ICT allowed for precise planning regarding implant positions,

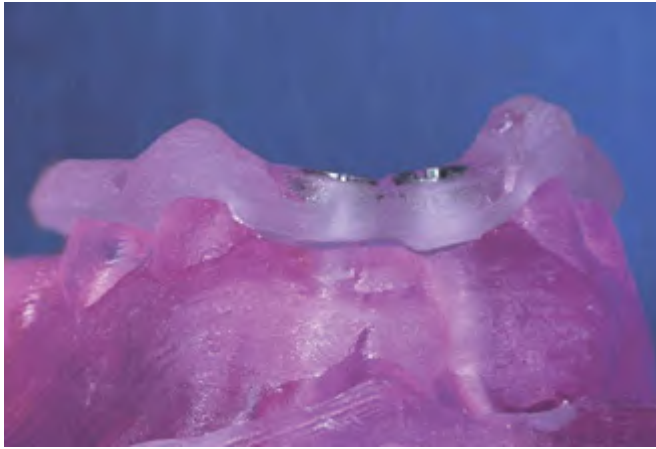


Figure 6.15. Laboratory facial view of a tooth-supported surgical guide in place on a stereolithographically constructed model of a partially edentulous maxillary segment.

and the images were also used for construction of the surgical guide and final prosthetic fabrication prior to surgery. They found that this technology was powerful and easy to use, and concluded that it will give clinicians a significant advance in implant dentistry.

INTERACTIVE COMPUTER SOFTWARE

The case in this chapter was performed using SimPlant 12.0 (Materialise Dental, Glen Burnie, MD). This software program offers clinicians a solution for implant treatment from treatment planning to construction of the surgical guides and the provisional implant restorations (*SurgiGuide Cookbook* 2007).

The SimPlant software contains an open design feature in that the software is compatible with all CT and cone beam scanners. The software is also compatible with most major implant types and manufacturers. Implant designs and specifications are contained within the implant library, and the library is updated on a regular basis.

This software program allows the construction of a surgical guide that will be used during the implant surgery by providing a link between the virtual treatment plan and the actual surgery (Figure 6.15). Guide tubes, in this case specific to the Biomet 3i Navigator™ System for CT Guided Surgery, will be placed into the surgical guides that will accurately position the surgical drills into their correct positions according to the treatment plan (Figure 6.16).

SURGICAL GUIDES

The surgical guide is the union of two components: the guide tubes and the contact (intaglio) surface of the surgi-



Figure 6.16. Notches within the occlusal surfaces of the master tubes can be visualized in this laboratory image of a computer-generated surgical guide.



Figure 6.17. Laboratory image of the intaglio surface of a tooth-supported surgical guide with two master guide tubes in place in an anterior maxillary segment. The tubes were placed, and the surgical guide was fabricated consistent with the treatment plan developed in the computer software program.

cal guides. These data points were generated from the CT scan with a scanning appliance in place. The intaglio surface can be made to fit onto the edentulous jaw, the mucosal tissues covering a jaw, or adjacent natural teeth (Figure 6.17). Due to the complex three-dimensional shapes of jaws and teeth, the fit of each surgical guide is unique and stable. The surgical guides are made with resin, using a stereolithographic process, and are customized for each particular patient.

MASTER TUBES

Master tubes are precision machined metal tubes that are used with drills of specific diameters, through a given surgical guide, in locations that were determined during the treatment planning process (Figure 6.18). The tubes provide predetermined depth stops for the twist drills and implant mounts during surgical implant placement. The master tubes are machined with two notches, 180 degrees apart (Figure 6.19). The notches were designed to provide positive interlocks with implant and analog mounts to ensure that the “timing” of the implant hex in implant analogs in a master cast is replicated with the timing of the implant hex intraorally.

PROSTHETIC LABORATORY KIT—IMPLANT ANALOG MOUNTS

The Navigator Laboratory Kit (Biomet 3i) is comprised of implant analog mounts (Table 6.1) that are used in



Figure 6.18. Laboratory illustration of a surgical guide with six master tubes in place.

conjunction with the master tubes in the surgical guide to position implant analogs in the guide prior to pouring a cast (Figure 6.20). The laboratory kit contains 12 analog mounts with the internal connection (Certain® Connection, Biomet 3i). The mounts are available in three diameters (3.4, 4, and 5 mm) and four lengths that have been identified as (1), (2), (3), and (4) (Figure 6.21). The laboratory technician will know which specific analog mount to use for each specific implant site because the mounts



Figure 6.19. Laboratory illustration of master tubes for 4-mm-diameter implants. Master tubes are available in two heights to compensate for the prolongation involved in each particular case. Each tube is machined with notches 180 degrees apart. The notches will serve as reference points for hex orientation in the placement of implant analogs into the master casts and implants into the edentulous sites intraorally.

TABLE 6.1. Navigator Laboratory Kit (Biomet 3i)

Components	Description	Item Number
Laboratory kit	Complete Navigator Laboratory Kit	SGLKIT
Laboratory tray	Navigator Laboratory Tray	SGLTRAY
	Navigator Certain Analog Mount, MicroMiniplant™ × 1(L)	MSGIAM1
	Navigator Certain Analog Mount, MicroMiniplant × 2(L)	MSGIAM2
	Navigator Certain Analog Mount, MicroMiniplant × 3(L)	MSGIAM3
	Navigator Certain Analog Mount, MicroMiniplant × 4(L)	MSGIAM4
	Navigator Certain Analog Mount, 4.1 mm (D) × 1(L)	SGIAM41
	Navigator Certain Analog Mount, 4.1 mm (D) × 2(L)	SGIAM42
	Navigator Certain Analog Mount, 4.1 mm (D) × 3(L)	SGIAM43
	Navigator Certain Analog Mount, 4.1 mm (D) × 4(L)	SGIAM44
	Navigator Certain Analog Mount, 5 mm (D) × 1(L)	SGIAM51
	Navigator Certain Analog Mount, 5 mm (D) × 2(L)	SGIAM52
	Navigator Certain Analog Mount, 5 mm (D) × 3(L)	SGIAM53
	Navigator Certain Analog Mount, 5 mm (D) × 4(L)	SGIAM54

L, length; D, diameter.



Figure 6.20. Laboratory illustration of the Navigator Laboratory Kit. Implant analog mounts are available for 3.4-, 4-, and 5-mm-diameter internal connection implants. They have been machined in four lengths, corresponding in length to the implant mounts in the surgical kit.



Figure 6.21. Laboratory illustration of four implant analog mounts in four different lengths. Laboratory technicians will identify each specific mount for use within the surgical guide from the treatment plan.

have been identified within the treatment plan (Figure 6.22). The analog mounts feature notches in the occlusal aspects of each mount as mentioned above, which hold the implant analogs in place within the three planes of space, including rotationally, within the master tubes. Positive machinings in the analog mount thumbwheels fit into both notches of the master tubes to ensure accurate

2	3	4	5	6	7
IFOS511	IFOS411	IFOS485	IFOS485	IFOSM311	IFOS4
5/3.1	4.1/2.6	4.1/2.6	4.1/2.6	3.4/2.4	4.1/2.1
11.1	11.1	8.1	8.1	11.1	12.6
Implant Placement					
(2)	(2)	(2)	(2)	(2)	(1)
5	4	4	4	4	4
5	4	4	4	3	4
2(B)/3	2(B)/1	2(A)/1	2(A)/1	2(B)/1	2(B)/1
3.25(B)/4	3(B)/2	3(A)/2	3(A)/2	2.75(B)/1	3(B)/2
3.85(B)/4	/	/	/	/	/
5	4	4	4	3	4
5(2)	4(2)	4(2)	4(2)	3(2)	4(1)
5	4	4	4	3	4
Analog Placement					
5(2)	4(2)	4(2)	4(2)	3(2)	4(1)
IILA5	IILA20	IILA20	IILA20	IIMILA	IILA20

Figure 6.22. Photograph of a treatment plan. The bottom two lines are the laboratory portion of the treatment plan. These two lines indicated which implant analog mounts were to be used with which specific implant analog in each specific implant site.

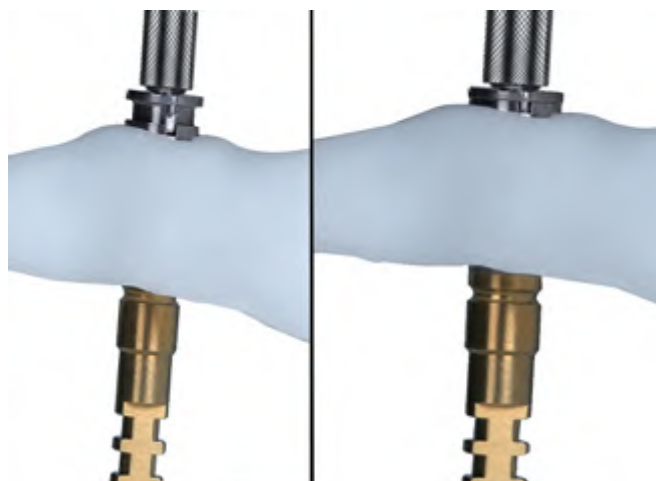


Figure 6.23. Laboratory illustration of two implant analog mounts within a surgical guide. The left implant analog mount was not seated within the master tube; the right implant analog mount was correctly seated within the master tube.

transfer of the hex orientation from the master cast to the mouth (Figure 6.23).

SURGICAL KIT COMPONENTS

In order for an implant surgeon to place implants, implant mounts from the surgical kit are used through the master tubes in the surgical guide. The implant mounts were machined for use with Biomet 3i Certain Connection



Figure 6.24. Laboratory illustration of four implant mounts in four different lengths. The use of each implant mount will be delineated in the surgical portion of the treatment plan and will identify each specific mount for use within the surgical guide from the treatment plan.



Figure 6.25. Laboratory illustration of the surgical kit. The implant mounts are in the second, deeper layer of the kit. A portion of the implant mounts for the 4-mm-diameter and all of the implant mounts for the 5-mm-diameter implants are visible in this figure.

implants (3.4-, 4-, and 5-mm diameters) and four lengths identified as (1), (2), (3), and (4) (Figure 6.24). There are therefore 12 unique implant mounts. Within one treatment plan, an implant mount may be called for several times; five complete sets of implant mounts are available in each surgical kit (60 total mounts) (Figure 6.25). Implant mounts were designed to be depth specific, with a flange on the occlusal aspect of each mount for depth stops. A “spline” feature on the flange of each implant mount may be used



Figure 6.26. Laboratory illustration of two implant mounts within a surgical guide. The left implant mount was not aligned properly with the notches within the master tube; the right implant analog mount was correctly aligned with the notches within the master tube.

as visual references during implant placement to orient the hex connection of each implant within the master tube. The cutouts of each flange are aligned with the slots on each master tube. This ensures the accurate transfer of the hex orientation from the preoperative master cast to the implants intraorally (Figure 6.26).

FABRICATION OF A MASTER CAST FOR AN IMMEDIATE, FIXED PROVISIONAL PROSTHESIS

The appropriate implant analogs and implant analog mounts are selected as identified in the treatment plan. The implant analog mounts are placed into the implant analogs, the hexes are aligned, and the thumbscrews are threaded approximately two turns. The analog mount/implant analogs are placed through the master tubes in the surgical guide, consistent with the implant sites in the treatment plan. The above components are aligned with the notches in the master tubes, and the thumbscrews are completely hand tightened. (Note: Do not over tighten the above complexes before placing them into the master tubes as the analog mounts may be damaged [Figure 6.27].)

Apply a stone separating material to the intaglio surface of the surgical guide. Box the surgical guide as if it were an impression and inject a soft tissue replicating material around the implant analogs in conventional fashion (Figure 6.28). Vacuum mix dental stone consistent with the



Figure 6.27. Laboratory illustration of implant analogs accurately positioned in a surgical guide. The blue analogs are 4 mm in diameter; the gold analogs are 5 mm in diameter. All of the analog mounts have been accurately positioned within the master tubes.



Figure 6.28. Laboratory illustration of soft tissue replication material injected around the implant analogs within a surgical guide.

manufacturer's instructions for weight and water volume, and pour the master cast.

Place the scanning appliance onto the above master cast. Verify that the scanning appliance has been completely seated. Articulate the master cast with the opposing cast by using the previously made interocclusal record for the scanning appliance and mount the casts in a semiadjustable articulator (Figure 6.29).

ABUTMENT SELECTION FOR FIXED, SCREW-RETAINED PROVISIONAL PROSTHESES

Abutments for immediate, full-arch prostheses are generally chosen by the restorative dentist and dental laboratory technician. With CT treatment planning, the abutments may actually be selected with reasonable certainty at the treatment planning appointment. Prostheses may be either



Figure 6.29. Laboratory illustration of the newly made maxillary master cast, articulated with the opposing mandibular cast, with an interocclusal record in a semiadjustable articulator. The maxillary scanning appliance was fit to the maxillary master cast prior to the articulator mounting.

cement or screw retained; abutments are chosen consistent with those designs. The benefits and limitations regarding cement- and screw-retained restorations have been previously discussed in Chapter 1 and will not be repeated here.

For screw-retained prostheses, the authors prefer the conical abutment series of abutments from Biomet 3i. They are available in straight, 17-degree, and 25-degree pre-angled configurations (Figure 6.30). The collar heights for each abutment are selected by measuring the sulcular depths around each implant analog in the master cast. If subgingival margins are desired, subtract 1 mm from the sulcular depth measurements. Next, select the appropriate angulation: straight, 17, or 25 degrees. In CT-guided surgery, this has already been determined from the treatment planning program software (Figure 6.31). Allow approximately 2 mm of interarch distance between the occlusal aspects of the abutments and the opposing dentition.



Figure 6.30. Straight (4-mm collar height); 17-degree (4-mm collar height); 25-degree (4-mm collar height) conical abutments (ICA004, ICA4417, ICA4425 [Biomet 3i], respectively, left to right).

Place the selected abutments into each analog by lining up the hex connections in the abutment/implant interface. With this internal connection system, the technician should hear and feel the clicks associated with accurate seating.

FABRICATION OF A SCREW-RETAINED PROVISIONAL PROSTHESIS

In a screw-retained prosthesis, temporary cylinders may be placed onto the conical abutments and then processed into the acrylic resin prosthesis. For the Biomet 3i components used in this case (conical abutments), conical abutment temporary cylinders (CC300, Biomet 3i) will be used. Nonhexed cylinders are used with multiple unit prostheses. Place the temporary cylinders onto the conical abutments with laboratory retaining screws (WSK15, Biomet 3i) (Figures 6.32 and 6.33). The large hex driver is used to tighten the lab screws.

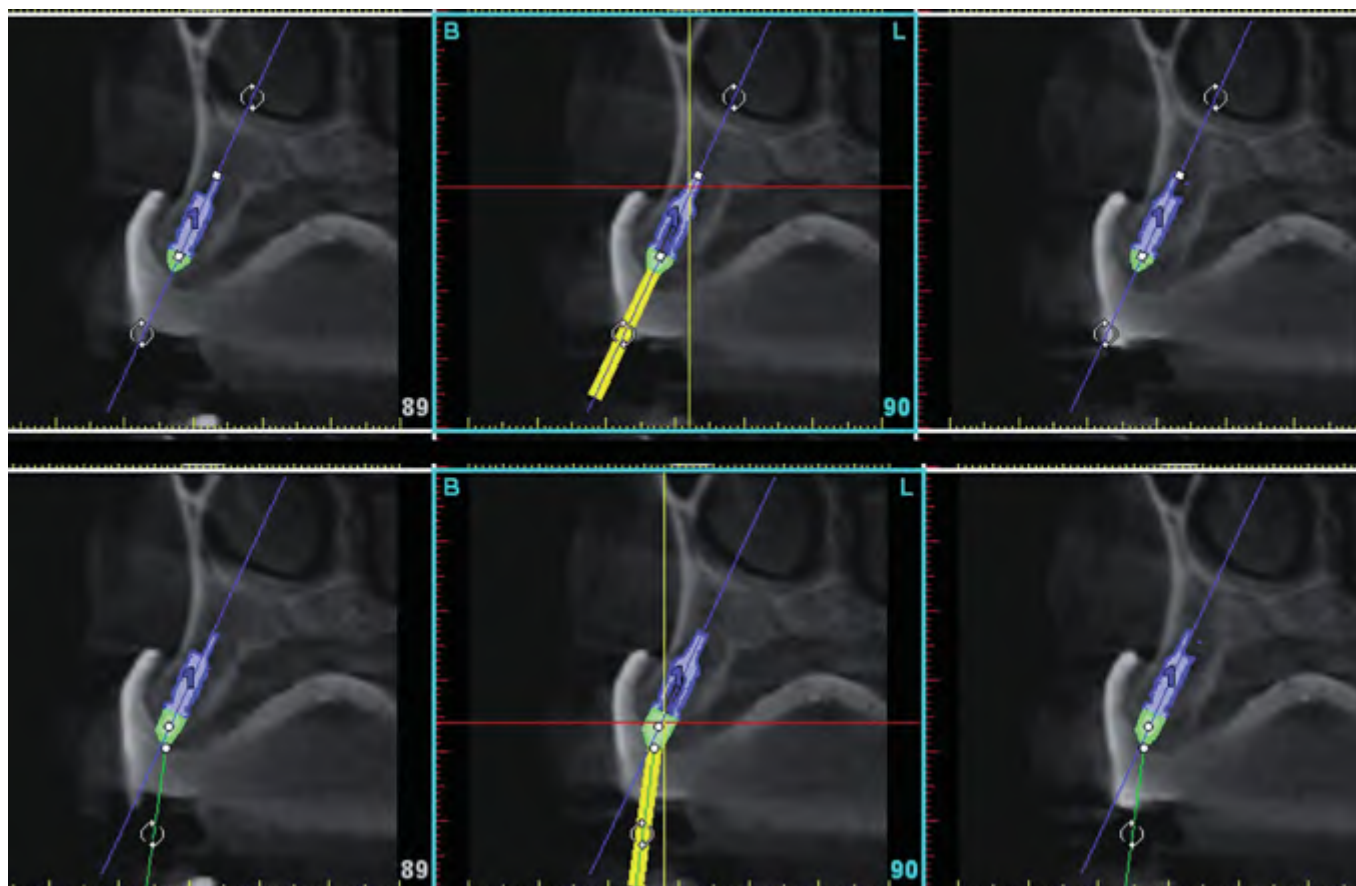


Figure 6.31. This is a screen shot of a computer monitor, with cross-sectional images from the patient's left posterior maxillae. In this case, a 4 × 13-mm implant was placed within the alveolus. The facial surfaces of the scanning appliance, relating the planned positions of the artificial teeth in the area, were present on the screen. A 4-mm conical abutment was initially placed on this implant. The screw access opening for a 4-mm conical abutment would exit the prosthesis in the midfacial surface of the artificial tooth (top images). The bottom images identified the same cross section as above. A 17-degree preangled conical abutment virtually replaced the straight conical abutment and changed the screw access opening to exit within the occlusal surface of the artificial tooth.



Figure 6.32. Temporary cylinder (CC300) for a conical abutment (left). Temporary cylinders are machined with and without hexes, for single- and multiple-unit restorations, respectively. Laboratory retaining screws (right) are used with the temporary cylinders and conical abutments.

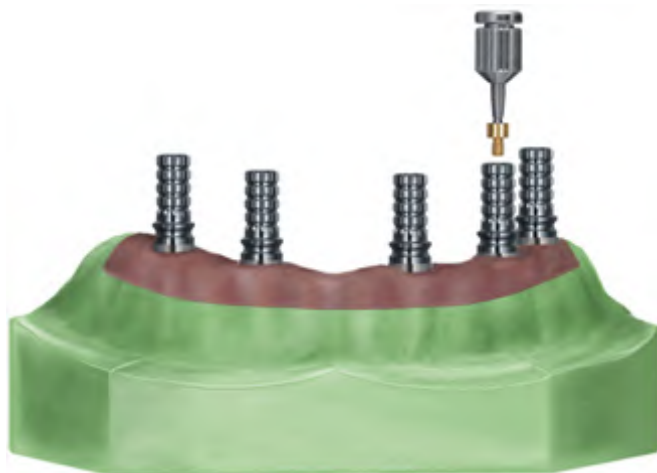


Figure 6.33. In this illustration, a large hex driver was used to place a clinical retaining screw into a temporary cylinder. Clinical retaining screws (GSH30) should not be used in the laboratory.

Screw-retained fixed provisional prostheses may be fabricated in a number of different ways: waxing and processing as in conventional complete dentures; autopolymerizing acrylic resin and vacuum-formed templates; or with light-cured resins. The authors prefer to duplicate the master cast with the abutments and temporary cylinders in place, articulate the cast with the previously mounted opposing

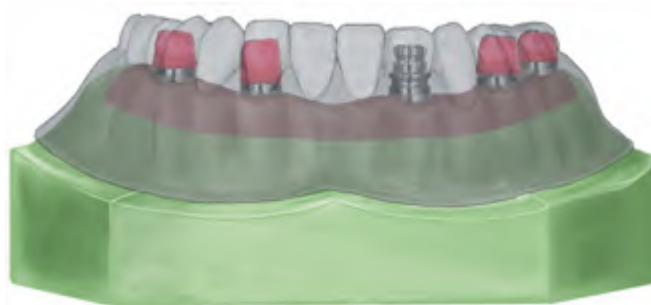


Figure 6.34. This is a laboratory illustration of a master cast with the abutments and temporary cylinders in place. A vacuum-formed index has been fitted to the cast prior to injection of autopolymerizing acrylic resin into the index.



Figure 6.35. Laboratory illustration of the laboratory processed fixed, screw-retained prosthesis after it was adjusted, finished, and polished prior to delivery to the clinicians on the day of surgery.

cast, and then wax and process the prosthesis (Figure 6.34). Once the acrylic resin has set, the prosthesis is removed from the duplicate cast and fitted back onto the original master cast. The prosthesis is adjusted, finished, and polished (Figure 6.35).



Figure 6.36. Occlusal view of a screw-retained prosthesis fitted back onto the original master cast with the temporary cylinders and abutments in place. In order to optimize the clinical fit of a screw-retained prosthesis intraorally, the authors prefer to process only one of the cylinders to the prosthesis in the laboratory with autopolymerizing acrylic resin. The remaining cylinders will be picked up with acrylic resin after the processed cylinder has been attached to its corresponding abutment intraorally.

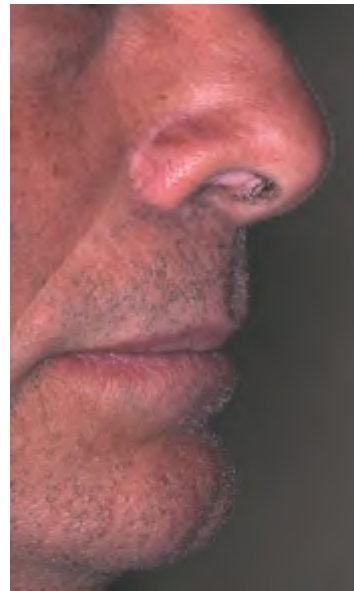


Figure 6.38. Extraoral, profile image of the patient with his existing dentures in place, in centric occlusion. The vermilion border of the upper lip was less pronounced than would otherwise be expected.



Figure 6.37. Extraoral, anterior image of the patient with his existing dentures in place, in centric occlusion. The vertical dimension of occlusion was decreased from the original condition, and the nasolabial folds were more prominent than normal.



Figure 6.39. Extraoral image of the patient with his dentures in place, smiling. Note the reverse smile line associated with the anterior denture teeth. Also note that more teeth are visible in the right posterior segments than in the left posterior segments.

It is the authors' experience that it is unlikely for a multiunit fixed, screw-retained prosthesis to go to place passively onto the implants. Instead of processing all of the temporary cylinders to the prosthesis in the laboratory, the authors prefer to process just one cylinder to the provisional prosthesis, leaving the remaining cylinders to be picked up clinically (Figure 6.36).

CLINICAL PATIENT PRESENTATION

A 52-year-old male presented to the periodontist's office with a chief complaint, "I want to get rid of my old dentures. I want dental implants and I don't want to have to take my teeth out" (Figures 6.37–6.39).



Figure 6.40. Anterior, intraoral image of the patient in centric occlusion, with his preexisting dentures.

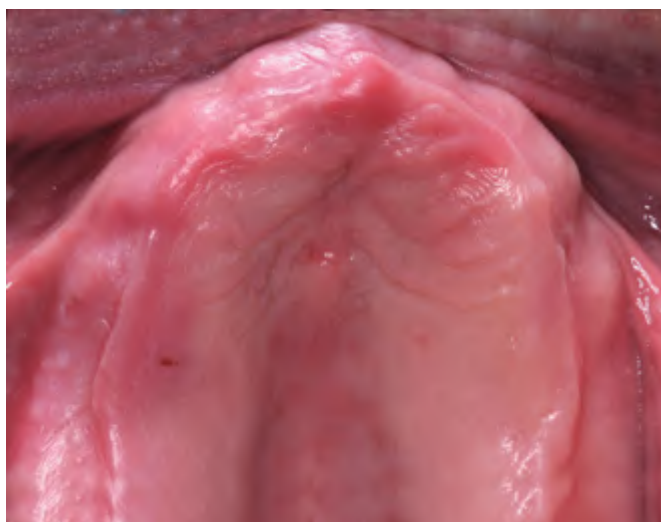


Figure 6.42. Intraoral image of the edentulous maxillae that had mild resorption and a broad edentulous ridge. There was an adequate amount of keratinized tissue throughout the ridge.



Figure 6.41. Anterior, intraoral image of the patient in centric occlusion, with his preexisting dentures in place. The vertical black line corresponds to his facial midline. Note that the dental midline of the maxillary denture is off to the right of the facial midline approximately 4 mm.

This patient's maxillary teeth were extracted approximately 3 years previous to his presentation as noted above. His edentulous maxillae had undergone uneven, normal resorption (upward and posterior), and resulted in a somewhat ill-fitting, displaced maxillary denture. The maxillary denture's midline was displaced to the right of the patient's facial midline (Figures 6.40 and 6.41).

Intraorally, the patient presented with a broad edentulous maxillary ridge and a significant amount of fixed, keratin-



Figure 6.43. Intraoral image of the edentulous mandible. Two osseointegrated implants had been functioning with resilient overdenture attachments for the previous 3 years. This mandibular ridge had undergone minimal vertical and horizontal resorption.

ized attached tissues (Figure 6.42). The mandible had already been treated with dental implants 3 years previous to this presentation (Figure 6.43). The mandible had undergone minimal resorption and also presented with a reasonable amount of fixed, keratinized tissue. The edentulous jaws had resorbed, but a Class I skeletal relationship was still maintained (Figures 6.44–6.46). The patient was dissatisfied with the function and retention of the mandibular implant-supported overdenture.



Figure 6.44. Anterior intraoral image of the patient's edentulous jaws. Neither jaw experienced significant vertical or horizontal resorption.



Figure 6.45. Lateral intraoral image of the patient's edentulous jaws. The resorbed jaws were considered to be in a Class I skeletal relationship.



Figure 6.46. Lateral intraoral image of the patient's edentulous maxillae with the mandibular implant-supported overdenture in place. This image confirmed that the edentulous jaws underwent minimal anterior/posterior resorption, and the patient was a candidate for fixed implant-retained prostheses in both jaws.



Figure 6.47. This is a screen shot of the preoperative, panoramic CT scan that demonstrated the presence of two osseointegrated implants in the anterior mandible and adequate surgical volume (in two dimensions) for implant placement.

RADIOGRAPHS

The implant surgeon recently purchased an in-office cone beam CT scanner. He now uses the CT scanner for his diagnostic radiographs (Figure 6.47). This radiograph demonstrated that the patient had, in two dimensions (buccal/lingual and vertical), adequate bone volume for implants in the anterior and posterior mandibular segments. The advantage of this protocol is that the surgeon can view the patient's anatomy in three dimensions. If so desired, the diagnostic imaging can be accomplished with the scanning appliance in place.

DIAGNOSIS

As a result of the physical and radiographic examinations, the following diagnoses were established:

1. Edentulous maxillae with mild/moderate bone resorption
2. Edentulous mandible with two osseointegrated implants in cuspid positions; mild/moderate resorption

3. Ill-fitting dentures
 - a. Maxillary denture midline displaced to the right of the facial midline by approximately 4 mm
 - b. Decreased vertical dimension of occlusion
 - c. Asymmetric smile
4. Adequate bone volume for implant placement
 - a. Six to eight maxillary implants
 - b. Six to eight mandibular implants
5. Class I skeletal jaw relationship

ASSESSMENT

This patient presented with ill-fitting dentures and a desire to have implant-retained fixed prostheses. He presented with adequate bone for consideration for implants and adequate space for fixed implant prostheses in both jaws. The skeletal jaw relationship was satisfactory, and he had minimal anterior/posterior resorption of the edentulous jaws. The maxillary edentulous ridge provided almost all of the lip support that was needed for optimal aesthetics. The patient presented as an excellent candidate for placement of multiple implants and immediate fixed provisional prostheses. To minimize the morbidity associated with implant placement and immediate occlusal loading for fixed provisional prostheses in both jaws, the authors felt that a CT-guided surgical protocol, with laboratory fabrication of the provisional prostheses, would be the treatment of choice. The CT scan would also provide the authors with an appreciation of the bone density in both jaws, which could have a bearing on the decisions to proceed with immediate occlusal loading.

TREATMENT PLAN

The following treatment plan was discussed with and agreed upon by the patient, his spouse, the implant surgeon, the prosthodontist, and the dental laboratory technician:

1. Construction of wax dentures that optimized the vertical dimension of occlusion, lip support, and centric jaw relationship, and aligned the dental and facial midlines
2. Fabrication of CT scanning appliances
3. CT scans of the edentulous jaws with scanning appliances in place
4. Treatment planning with the CT scans and computer software to optimize the positions of the implants consistent with the planned location of the teeth within the

prostheses; this would also include an analysis of the bone densities in the proposed implant sites

5. E-mail the data to the computer software manufacturer for fabrication of the surgical and prosthetic protocols
6. Fabrication of computer-generated stereolithographic surgical guides
7. Laboratory fabrication of master casts from the surgical guides and articulator mountings
8. Laboratory placement of the abutments, consistent with the prosthetic treatment plan
9. Fabrication of the fixed, provisional, implant-retained provisional prostheses
10. Clinical appointment for implant placement, abutment connection, and insertion of fixed, implant-retained prostheses

CONSTRUCTION OF WAX DENTURES

Definitive impressions and diagnostic casts were made of the edentulous jaws with stock impression trays (Figures 6.48 and 6.49). The mandibular impression also recorded



Figure 6.48. Laboratory occlusal view of the mandibular diagnostic cast. The master cast was fabricated with transfer implant impression copings. Healing abutments were placed onto the analogs that duplicated the healing abutments in place intraorally on the implants. This simplified construction of the mandibular record base and facilitated the jaw relation records. Vertical view of the healing abutments used in the master cast (left inset). Occlusal view of the healing abutments used in the master cast (right inset). The large number on the left is the height of the healing abutment; the numerator is the emergence profile, and the denominator is the size of the implant restorative platform.

the location of the mandibular implants with transfer implant impression copings.

The purposes of record bases and occlusion rims are to provide a means to record accurate jaw relation records, maintain the teeth in the wax setups for the wax try-ins, and to evaluate the accuracy of the initial jaw relation records. Dentists use record bases and occlusion rims to transmit important information to dental laboratory techni-



Figure 6.49. Laboratory occlusal view of the maxillary diagnostic cast.

cians. Jaw relationships, midlines, high and low lip lines, cuspid lines, amount of horizontal and vertical overlaps, and the requisite support for the lips and cheeks can be transferred to the laboratory via the articulator mounting and denture setup. The success of the prosthodontic treatment will, oftentimes, depend on the accuracy of this information.

Record bases were made from light-cured laboratory resin (Triad®, Dentsply International, York, PA) on both casts; a wax occlusion rim was attached to the maxillary record base. Jaw relation records were made intraorally, and the casts were mounted on a semiadjustable articulator with the incisal guide pin set at zero (Figures 6.50–6.54).

The clinical appointment for accurately establishing jaw relationships is sometimes overlooked by clinicians (Phoenix and others 2003). It is absolutely essential that the jaw relation record be accurate relative to occlusal vertical dimension and the centric jaw relationships. The goal in developing an occlusal scheme in implant prosthodontics is to establish and maintain a harmonious relationship with the oral structures/implants and to provide mastication that is efficient and aesthetically acceptable. Occlusal harmony must be present in centric occlusion/ relation and all eccentric positions.

Denture teeth may be made from porcelain, acrylic resin, composite resin, and resin/metal combinations. Each of the different types of teeth has their own advantages and disadvantages. The authors prefer to use acrylic resin

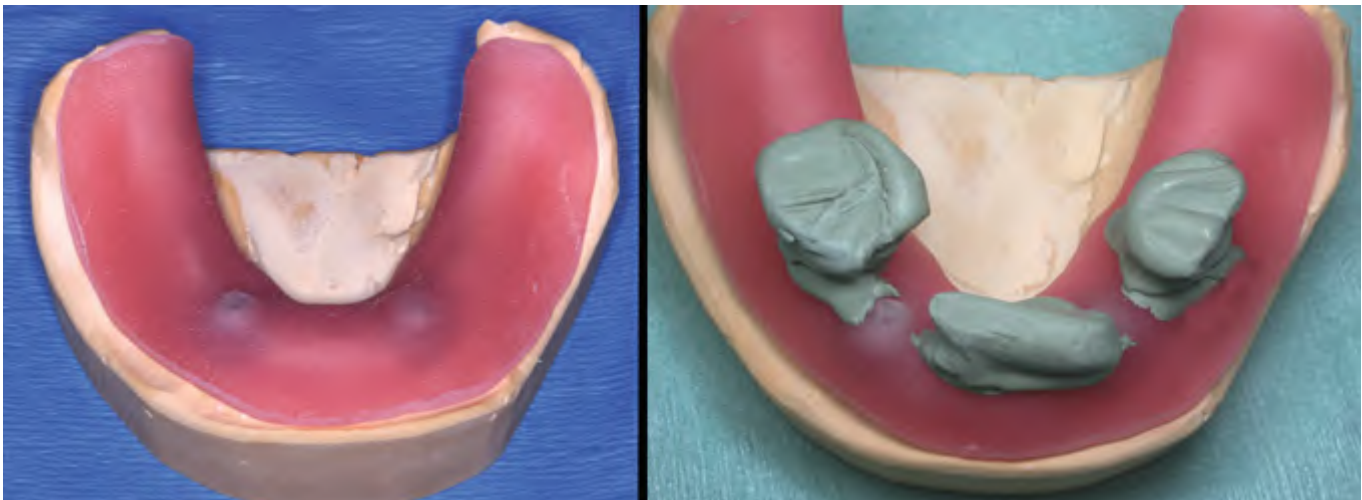


Figure 6.50. Occlusal view of the mandibular record base prior to the clinical jaw relation records appointment (left). Laboratory occlusal view of the mandibular record base after the jaw relation record was made (right). The anterior gray modeling compound stop was made first and recorded the initial, tentative vertical dimension of occlusion. The posterior stops were then added to the record base with gray modeling compound at the predetermined vertical dimension of occlusion. The mandibular record base actually functioned as a record base with two overdenture abutments. This significantly increased the stability of the record base during jaw relation records.



Figure 6.51. Occlusal view of the maxillary record base with occlusion rim. After the occlusion rim was contoured for proper orientation of the occlusal plane, lip support, and incisal display at rest, two V-shaped notches were carved into the posterior sections by the clinician in order to make the centric jaw relation record.



Figure 6.53. The casts were placed into the record bases and articulated together.

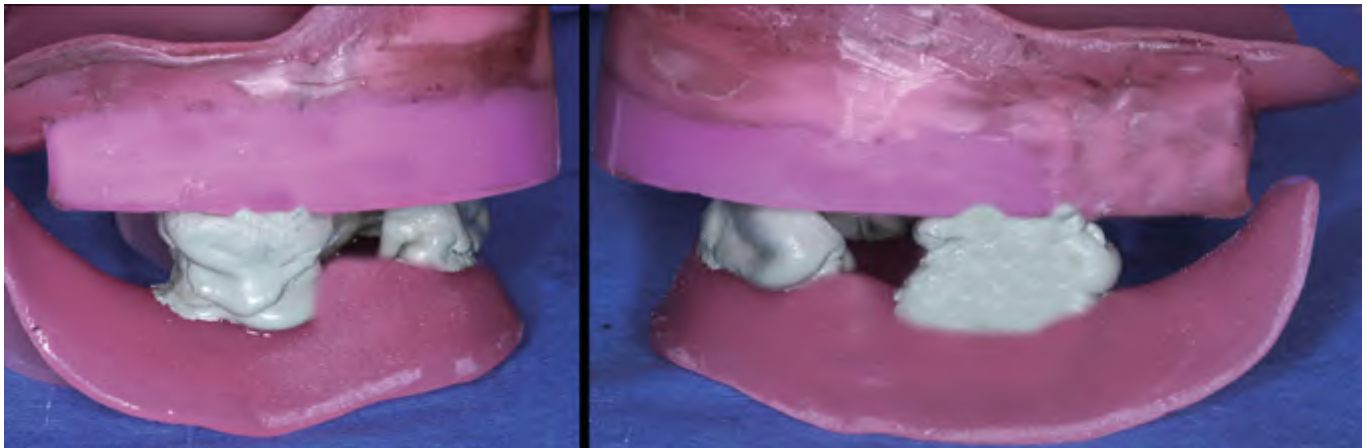


Figure 6.52. The occlusion rims articulated without the casts. Right: right posterior segments. Left: left posterior segments. It is essential that there are no interferences present between the record bases; only the interocclusal records should be in contact with each other.

denture teeth because of their versatility, availability, and aesthetics. Anterior teeth may be selected consistent with the patient's natural teeth, or they may be changed as per the patient's wishes. This holds true for both shade and mold. In complete denture prosthodontics, the authors prefer to let patients select their own shades. Mold selection is based upon two factors. Perhaps the more important factor is related to the space that has been created by tooth loss. In edentulous cases, it is important to remember

that the artificial teeth need to be placed where the natural teeth were originally located, not in relation to the present shape and location of the residual ridge.

Under some circumstances, patients may wish to change their basic tooth shape and ask the dentist for assistance. There are numerous techniques available to accomplish this. The readers are referred to textbooks on complete denture prosthodontics.

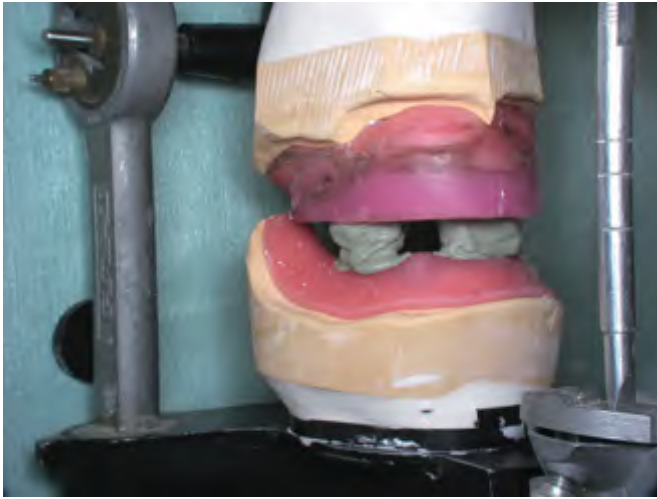


Figure 6.54. The casts were mounted in a semiadjustable articulator with the incisal guide pin set at zero. The occlusal plane was placed parallel to the horizon, in the center of the articulator. The maxillary midline was placed consistent with the vertical location of the incisal guide table.



Figure 6.55. Right laboratory view of the casts mounted in the articulator, without the record bases. Note that there was minimal anterior/posterior resorption of the jaws and that there was adequate interocclusal clearance between the edentulous ridges.



Figure 6.56. Wax dentures prior to the clinical try-in appointment: Right lateral oblique laboratory view (left side of image); left lateral oblique laboratory view (right side of image).

The second factor in mold selection is the overall shape of the teeth. Teeth are generally divided into four basic forms: square, tapering, square tapering, and ovoid. Tooth shapes may be correlated with facial forms. Again, clinicians generally use their individual experiences to select teeth appropriate for a given patient.

The denture teeth in this case were set consistent with the contours of the maxillary occlusion rim. Twenty-degree

teeth were used in the posterior segments. These teeth were set for optimal centric contacts and group function occlusion in right and left working movements (Figures 6.55–6.57).

CLINICAL TRY-IN OF THE WAX DENTURES

The wax dentures were tried in, the jaw relation records were verified, and the patient was pleased with the vertical



Figure 6.57. Right laboratory view of the casts mounted in the articulator, with the mandibular wax denture in place. Note the horizontal and vertical relationships between the labial surface of the anterior maxillary edentulous ridge and the labial surfaces of the mandibular anterior denture teeth. This gave the clinicians insight that this patient would not need a labial flange to support the upper lip and that a fixed implant prosthesis could be fabricated without aesthetic compromise.



Figure 6.58. Anterior clinical image of the patient with the wax dentures in centric occlusion. The dental midlines lined up with the facial midline.

dimension of occlusion, lip support and incisal display during speaking, smiling, and at rest (Figures 6.58–6.60).

FABRICATION OF CT SCANNING APPLIANCE

The mandibular wax denture was duplicated in conventional fashion with a denture flask (Figure 6.61). Dental stone was vacuum mixed and vibrated into the bottom half



Figure 6.59. Anterior facial image of the patient smiling with the wax dentures in place. The smile was asymmetric, with more teeth visible on his right side than on his left side. The reverse smile line present in the original dentures was corrected. This was consistent with the patient's preoperative desires.

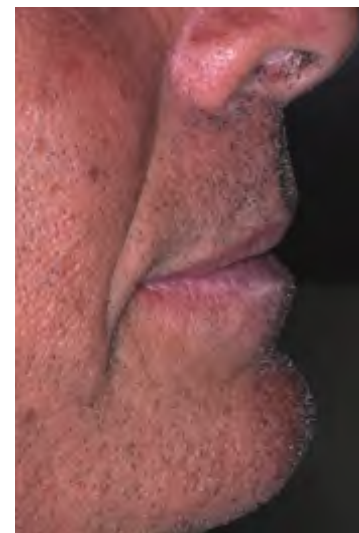


Figure 6.60. Clinical profile image of the patient with the wax dentures in place at the vertical dimension of rest position. The patient was pleased with the vertical dimensions of rest and occlusion, as well as the lip support provided by the wax dentures.

of the flask. The mandibular wax denture and cast were placed into the stone (intaglio surface down). The stone ended at the land area of the cast. A separating material (Isodent, Kerr Manufacturing Co., Romulus, MI) was mixed, applied to the stone in the flask and the wax denture, and allowed to dry. The top part of the flask was placed onto the bottom part of the flask, and additional dental stone was vacuum-mixed and poured into the top part of the flask. The lid was placed and the stone was allowed to set.



Figure 6.61. Laboratory illustration of the two parts of a denture flask prior to construction of an acrylic resin scanning appliance. The wax denture has been removed.

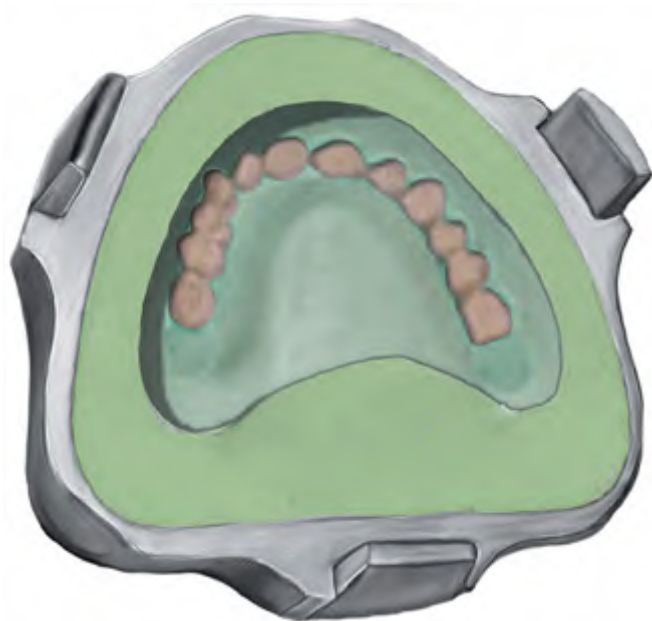


Figure 6.62. Laboratory illustration of the upper part of the denture flask after the 30% barium sulfate/70% autopolymerizing acrylic resin mix was poured into the impressions of the denture teeth.

The two portions of the flask were separated, and the wax denture was removed.

A mixture of 30% barium sulfate (E-Z-HD Barium Sulfate for Suspension 98%W/W, E-Z-EM Canada, Inc., a subsidiary of E-Z-EM Inc., Westbury, NY) and tooth-colored autopolymerizing acrylic resin (Jet Tooth Shade 6/1 Kit, Land Dental Manufacturing Co., Inc., Wheeling, IL) was mixed and vibrated into the impression of the occlusal surfaces of the mandibular wax denture in the flask (Figure 6.62).



Figure 6.63. Laboratory illustration of the polished scanning appliance.

Prior to polymerization of the acrylic resin/barium sulfate combination described above, a new mix that consisted of 10% barium sulfate and autopolymerizing acrylic resin was mixed and vibrated into the mold, on top of the previous mixture. The flask was closed and placed into a flask press, and the mixture was allowed to cure. The flask was opened and the scanning appliance was removed. It was finished and polished in conventional fashion with burs and flour of pumice (Figure 6.63).

All of the internal undercuts were removed from the scanning appliance, and the appliance was fitted back onto the master cast. The processing error was adjusted on the scanning appliance, and a laboratory interocclusal record was made with polyvinyl siloxane impression material (Figure 6.64). The scanning appliance was fitted to the patient's mouth and adjusted as needed to make sure that it was comfortable. The interocclusal record was verified as being accurate. The scanning appliance and the interocclusal record were sent back to the implant surgeon.

INTRAORAL CT SCAN

Since the periodontist had a cone beam CT scan in the office, the patient presented to him for the scan. The periodontist tried the scanning appliance into the patient's mouth and evaluated the appliance relative to the fit and soft tissue adaptation, the occlusal relationship with the mandibular denture, and the accuracy of the laboratory fabricated interocclusal record. All of the above were found to be satisfactory. The CT scan was accomplished without incident. The major benefit of CT-guided surgery is that the implant surgeon can precisely identify the locations of vital anatomical structures, as well as the amount of viable bone for implant placement, and the planned location of the artificial teeth in the prosthesis (Figure 6.65). The implants can be determined in terms of implant/abutment connection, diameter, length, and three-dimensional orientation. If abutments are to be used, the collar height, type, and amount of angle correction can also be determined (Figures 6.66–6.69).



Figure 6.64. Laboratory illustration of a scanning appliance on the maxillary cast, laboratory fabricated interocclusal record in place, and the mandibular cast mounted in an articulator.

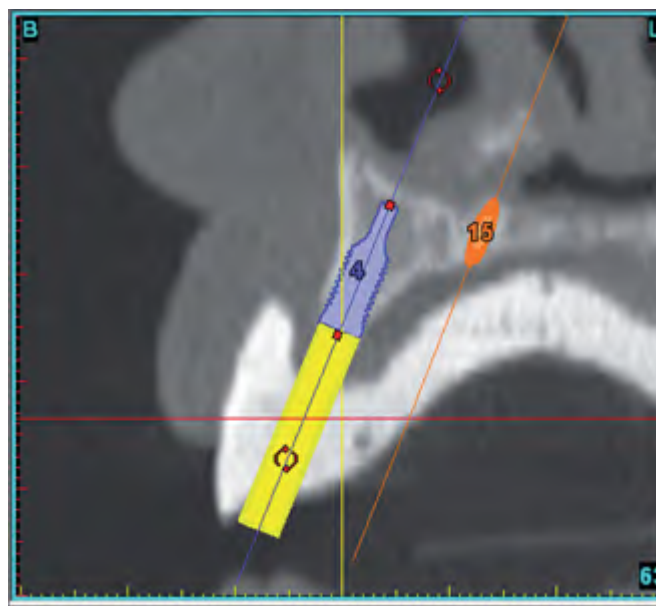


Figure 6.65. In this screen shot, a 4-mm-diameter implant has been planned for this particular site. The orientation of the implant was such that angle correction in an abutment was not required. Also, the peri-implant soft tissue depth was approximately 3 mm, so the implant team decided to go direct to the implant in the provisional prosthesis. The outline of the facial surface of the artificial tooth was clearly identified via the scanning appliance.

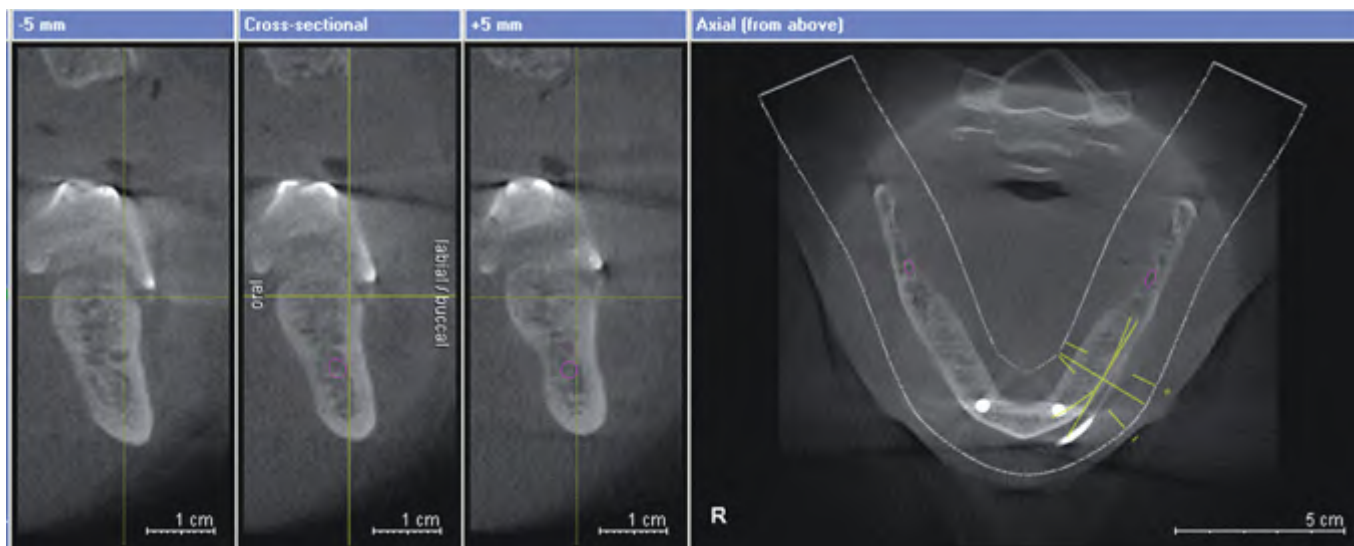


Figure 6.66. Screen shot of the left posterior mandibular segment's CT scan, with the scanning appliance in place. The location of the left inferior alveolar nerve was clearly seen (purple circle). The location of the slice was indicated by the line on the occlusal view of the mandible (right side of image).

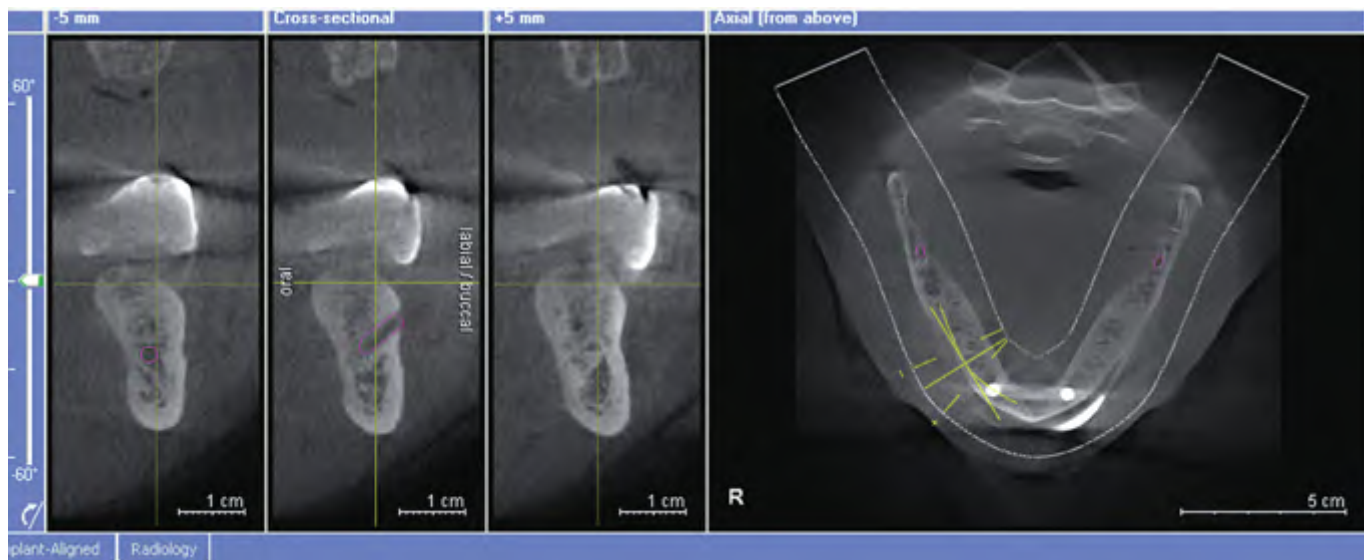


Figure 6.67. Screen shot of the right posterior mandibular segment's CT scan, with the scanning appliance in place. The location of the right mental nerve was clearly identified on the lateral cross-sectional image (left side of image). The location of the right inferior alveolar nerve was also clearly seen (purple circle). The location of the slice was indicated by the line on the occlusal view of the mandible (right side of image).

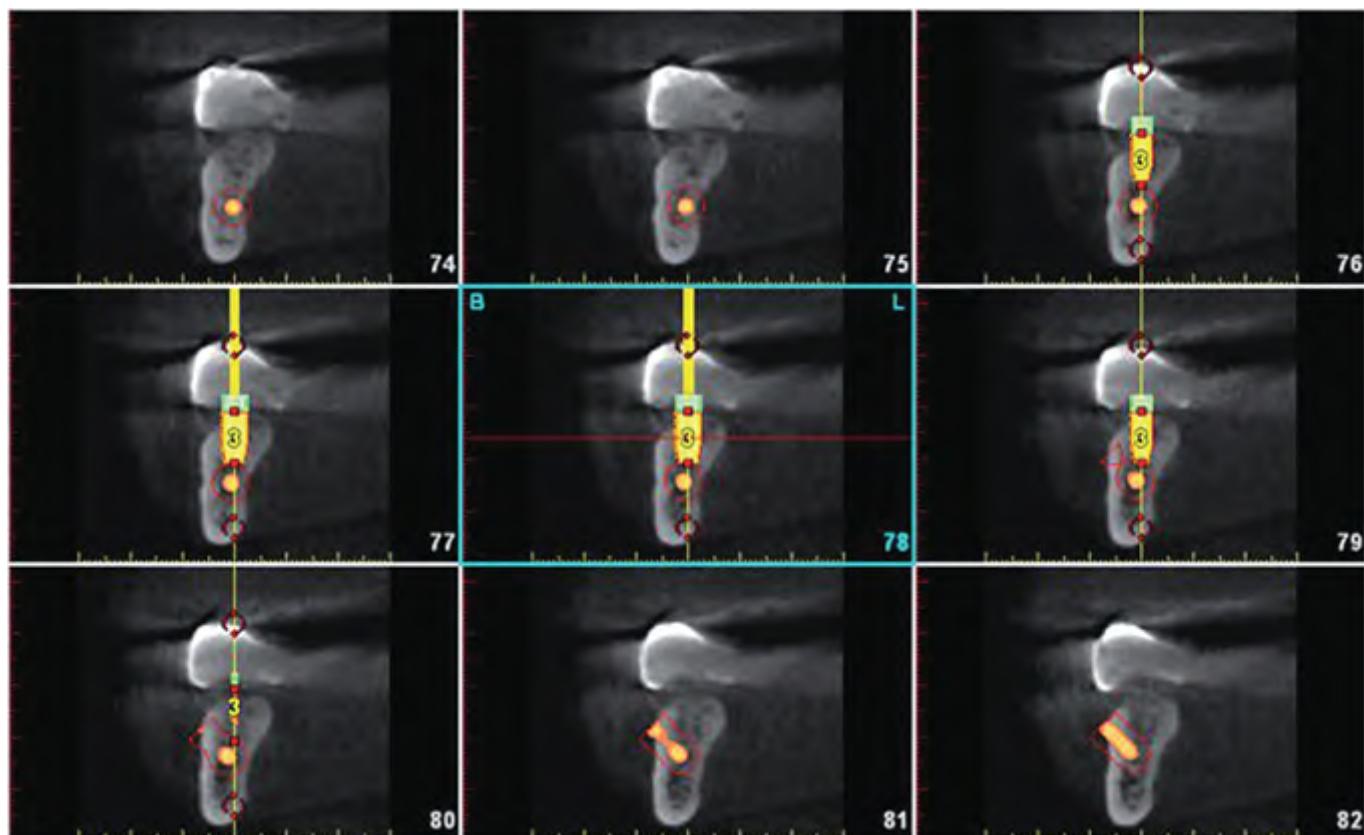


Figure 6.68. Screen shot of the right posterior mandible with a virtual 4-mm-diameter implant in place (slices 74 through 82). A virtual 3-mm conical abutment was also planned. The inferior alveolar canal and mental nerve are clearly visible. The virtual implant was placed within the alveolar bone, centered within the pontic on the scanning appliance.

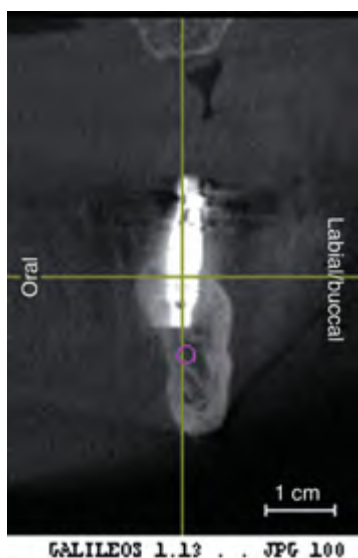


Figure 6.69. Radiograph of the right posterior implant 1 week post implant placement. The postoperative position corresponded with the virtual planned position in the diagnostic phase.



Figure 6.70. Occlusal view of the mandibular sterolithographic surgical guide. The blue master tubes were for 4-mm-diameter implants; the gold master tubes were for 5-mm-diameter implants.

Once the treatment plan was decided on by the implant team, the data were e-mailed to Materialise Dental at www.materialisedental.com for fabrication of the surgical guide and the treatment plan (Figures 6.70–6.72). In this case, SimPlant 12.02 was the software program used.

FABRICATION OF THE MASTER CAST WITH IMPLANT ANALOGS

The sterolithographic surgical guide provided the link between the treatment plan that was developed with the



Figure 6.71. Intaglio surface of the mandibular sterolithographic surgical guide. All of the internal undercuts had been removed so that the surgical guide would seat accurately to the mandibular edentulous tissues at the time of surgery.

Implant Label	4	5	6	7	8	9	10	11
Implant Reference	P05413	P05413	P05413	P05413	P05413	P05413	P05413	P05413
Planned position	4	5	6	7	8	9	10	11
Planned implant	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Depth Line	(2)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Torque Planch	5	4	4	4	4	4	4	4
Staple Drill	5	4	4	4	4	4	4	4
Drill 1 Handle	2(A)13	2(B)13	2(B)13	2(B)13	2(B)13	2(B)13	2(B)13	2(B)13
Drill 1 Handle	5.5(A)14	5.5(B)14	5.5(B)14	5.5(B)14	5.5(B)14	5.5(B)14	5.5(B)14	5.5(B)14
Drill 1 Handle	5.5(A)14	5.5(B)14	5.5(B)14	5.5(B)14	5.5(B)14	5.5(B)14	5.5(B)14	5.5(B)14
Top	5	4	4	4	4	4	4	4
Implant Mount	5(2)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)
Staple Position	5	4	4	4	4	4	4	4
Analog Placement	5(2)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)
Analog Type	BLAWS	BLAWS	BLAWS	BLAWS	BLAWS	BLAWS	BLAWS	BLAWS

Figure 6.72. This is a copy of the treatment plan as received from Materialise Dental. The implant numbers correspond to the order that the implants were treatment planned (1–8) and were not related to tooth sites. The prosthetic portion of the treatment plan was indicated on the last two lines under “Analog Placement.”

software program and the actual surgical positioning of the implants. Master tubes, consistent with the diameters of the implants to be placed, were precisely arranged within the surgical guide (Figure 6.73). The master tubes transferred the implant locations from the plan to the patient by accurately guiding the requisite drills and implants into their predetermined locations, orientations, and positions. The implant team was not responsible for selecting the



Figure 6.73. Illustration of 4-mm-diameter master tubes (4-mm length, left; 5.5-mm length, right). The notches (180 degrees apart) were machined for precise positioning of the implant analogs into the master cast.



Figure 6.74. Top view of the laboratory prosthetic kit that contained the analog mounts. The mounts are arranged for 3.4-mm-diameter implants in the top section, 4.1-mm-diameter implants in the middle section, and 5-mm-diameter implants in the bottom section. The mounts are also arranged according to length: 1, 2, 3, and 4. It is critical for dental laboratory technicians to correctly identify the mounts according to the computer-generated prosthetic treatment plan.

correct master tubes. This was determined by the software program.

Analog mounts may be purchased separately or in the prosthetic kit (Figure 6.74). Analog mounts are available in three diameters—3.4, 4.1, and 5 mm—and have been manufactured in four lengths (1, 2, 3, and 4) (Figure 6.75).



Figure 6.75. Analog mounts arranged in increasing lengths, 1–4 (left to right).



Figure 6.76. Initially, the implant analogs were attached to their corresponding analog mounts with minimal torque. The notches in the master tubes were engaged after the analogs and analog mounts were placed through the master tubes. Once the notches were engaged, the thumbscrews were tightened and secured the analog mounts in the master tubes. The prosthetic portion of the computer-generated treatment plan has been placed along the inferior edge of the image.

The appropriate analog mounts were selected, consistent with the instructions on the treatment plan, and attached to their corresponding implant analogs (Figure 6.76).

The implant analogs were placed into their respective analog mounts, the hexes were lined up, and the

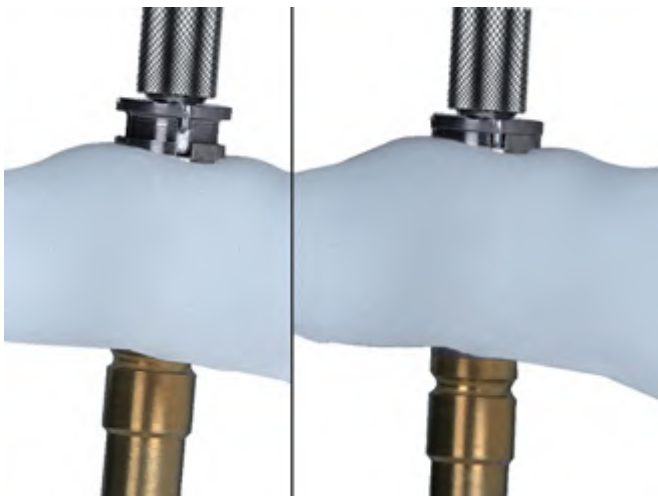


Figure 6.77. The illustration on the left demonstrates that the analog mount/analog complex was not seated into the master tube. The illustration on the right demonstrates that the analog mount/analog complex was seated correctly into the master tube.



Figure 6.78. Laboratory image of the implant mount/implant analog complexes in their correct positions within the surgical guide.

thumbscrews were threaded for approximately two turns. The analog mount/implant analog complexes were then placed into their respective master tubes, and the positioning pins were lined up between the analog mounts and the master tubes by engaging the positioning pins into the notches. The thumbscrews were hand tightened (Figures 6.77 and 6.78). It must be noted that over tightening the analog mounts outside of the master tubes may damage the analog mounts.

The occlusal surface of the surgical guide was placed into polyvinyl siloxane impression material for use as a base



Figure 6.79. Polyvinyl siloxane impression material was used to make a base prior to boxing the surgical guide.



Figure 6.80. Boxing wax was used to box the impression in conventional fashion.

(Figure 6.79). A separating medium was placed on the intaglio surface of the surgical guide. Polyvinyl siloxane impression material was injected onto the intaglio surface of the surgical guide and around the implant analogs. This impression material was used as the soft tissue replica. The surgical guide was boxed with wax, and the definitive cast was poured in vacuum-mixed dental stone (Figures 6.80 and 6.81). After the stone set, the thumbscrews were unscrewed, and the surgical guide was removed from the master cast (Figure 6.82).

The scanning guide was fitted onto this cast; the cast was mounted in the articulator with the preexisting laboratory fabricated interocclusal record.



Figure 6.81. Additional polyvinyl siloxane impression material was injected onto the intaglio surface of the surgical guide, around the implant analogs and implant mounts, to provide replication of the maxillary soft tissues.



Figure 6.82. This is an occlusal view of the definitive mandibular master cast after it was separated from the surgical guide. The implant analogs were in the precise positions as determined with the software program and other laboratory procedures.

LABORATORY ABUTMENT SELECTION AND PLACEMENT

Silicone indexes of the wax dentures had been made after the patient had agreed to the aesthetics and vertical dimension of occlusion (Figures 6.83 and 6.84). From the diagnostic workup with the software program, the implant team knew that angle corrections were not needed for any of the mandibular implants. Screw-retained prostheses



Figure 6.83. Right laboratory view of the silicone index of the mandibular wax denture after the patient had given his approval regarding aesthetics, vertical dimension, and lip support. This index would be used later in waxing the patterns for the mandibular framework and provisional prosthesis.

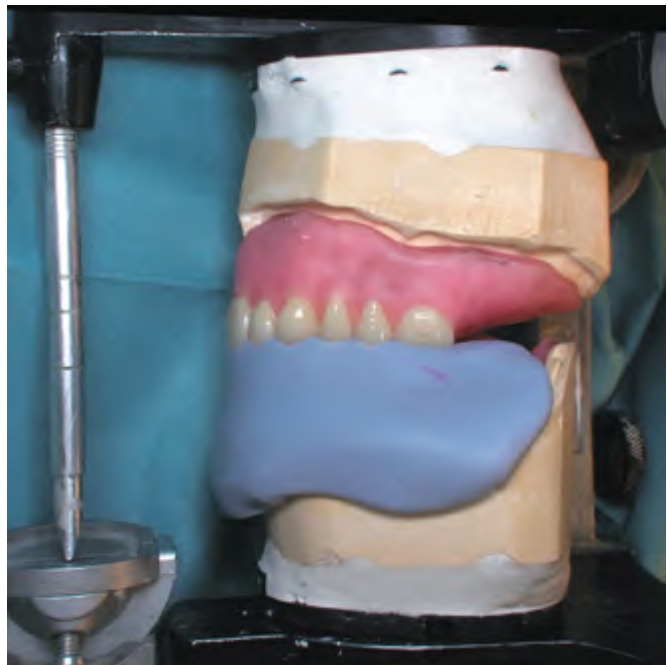


Figure 6.84. Left laboratory view of the silicone index of the mandibular wax denture after the patient had given his approval regarding aesthetics, vertical dimension, and lip support. This index would be used later in waxing the patterns for the mandibular framework and provisional prosthesis.



Figure 6.85. Illustrations of straight, 25-degree, and 17-degree preangled conical abutments.



Figure 6.86. This is an illustration of a conical abutment with a 3-mm collar (left) and a nonhexed temporary cylinder (right). Conical abutments are symmetrical. This abutment was machined with an internal abutment/implant connection. Temporary cylinders do not need to be hexed since they will be part of a multiunit fixed prosthesis.

provide more flexibility in terms of retrievability; it had been decided at the treatment planning stage to use conical abutments and nonhexed temporary cylinders.

For this implant team, one of the goals in abutment selection is to locate the margins of the mandibular abutments just above the gingival margins post implant placement. Therefore, 2- and 3-mm conical abutments were placed into their respective positions on the mandibular analogs. Nonhexed temporary cylinders were selected and adjusted as needed and placed onto the mandibular conical abutments (Figures 6.85–6.87).



Figure 6.87. Lingual occlusal view of the mandibular cast with the temporary cylinders in place on the conical abutments (not visible).



Figure 6.88. Laboratory image of the maxillary and mandibular wax dentures, mounted in the articulator from the wax try-in appointment. This articulator mounting was used in construction of the provisional prostheses.

FRAMEWORK FABRICATION (PROVISIONAL PROSTHESIS)

Since the patient indicated to the surgeon that he wanted to wear this prosthesis for at least 18 months, it was decided to reinforce the provisional prosthesis with a cast metal framework. The mandibular provisional prosthesis was waxed to full contour, simulating the contours of the wax denture (Figures 6.88–6.90). The wax pattern was cut back, sprued, and cast with a base metal alloy (Wiron® 99, Bego, Konstanz, Germany) (Figures 6.91 and 6.92).



Figure 6.89. Laboratory image of the mandibular wax patterns (provisional prosthesis) mounted in the articulator against the maxillary wax denture. The mandibular provisional prosthesis was waxed to full contour, consistent with the contours of the wax dentures.



Figure 6.90. Laboratory occlusal image of the mandibular wax pattern after it had been cut back from the full-contour wax pattern. A silicone index was made that identified the contours of the wax denture and placed onto the cast. This served as a reference for the dental laboratory technician during this procedure.

Wiron 99 is a corrosion-resistant, base metal alloy with a high modulus of elasticity (Table 6.2).

To decrease the labor associated with a 12-unit framework, the framework was not waxed to be cast to the abutment cylinders. Instead, it was waxed so that the framework copings encircled the mandibular abutments (Figure 6.93).

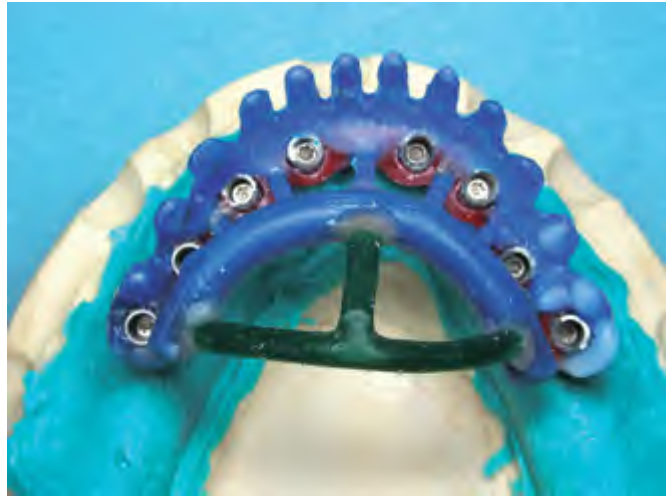


Figure 6.91. Laboratory occlusal image of the mandibular wax pattern after it was cut back, without the silicone index in place.



Figure 6.92. Laboratory facial image of the mandibular wax pattern after it was cut back, without the silicone index in place.

The space between the abutments and the framework would be occupied by autopolymerizing acrylic resin. The resin was to be used to attach the six cylinders for the recently placed implants to the framework at the clinical appointment. The two cylinders associated with the osseointegrated implants were processed to the framework since their locations were already known. This significantly decreased the complexity of the framework and resulted in decreased costs to the clinicians and patient. The framework was finished and polished.

PROVISIONAL PROSTHESIS

Waxing was completed per conventional prosthodontic protocols, and the prosthesis was flaked, boiled out, and

TABLE 6.2. Physical Properties and Characteristics of Wiron 99

	Standard Values
Color	Silver
Density	8.2g/cc ³
Melting range	1250–1310°C
Casting temperature	Approximately 1420°C
Coefficient of thermal expansion	
20–600°C	14.0 · 10 ⁻⁶ /K
25–500°C	13.8 · 10 ⁻⁶ /K
Ductile yield	25%
Elongation limit	330 MPa
Thermal contraction (solidus to room temp)	Approximately 2.2%
Modulus of elasticity	Approximately 205,000 MPa
Vickers hardness after casting	180
Composition by weight	
Ni	65%
Cr	22.5%
Mo	9.5%
Nb	1%
Si	1%
Fe	0.5%
Ce	0.5%
C	0.02% (max)

Note: From Directions for Use, Wiron 99.



Figure 6.93. Laboratory image of the intaglio surface of the cast framework. Note the circular shapes in the casting. This allowed the clinicians to place the framework, with virtually no adjustment, over the temporary cylinders intraorally. The space would be completely filled with autopolymerizing acrylic resin.



Figure 6.94. Laboratory occlusal image of the processed acrylic resin provisional prosthesis. Laboratory waxing screws were used to identify and maintain the screw access openings. The cylinders attached to the waxing screws were not processed into the provisional prosthesis.



Figure 6.95. Laboratory occlusal image of the processed acrylic resin provisional prosthesis. Try-in screws were used to retain the provisional prosthesis to the abutments and analogs.

processed with heat-cured acrylic resin (Lucitone 199®, Dentsply International) (Figures 6.94 and 6.95; Table 6.3). This resin is known as a “high-impact resin.” Latta and others (2002) reported in one study that Lucitone 199 had the highest Izod impact strength of four denture resins tested (4.05 ± 0.90 ft/lb). The occlusion was adjusted to correct for a minimal vertical processing error. The prosthesis was finished and polished in conventional fashion (Figures 6.96 and 6.97).

TABLE 6.3. Physical Properties of Lucitone 199

Residual MMA Content	2.2% (% mass fraction) maximum
Type and Class (according to ADA specification #12)	Type 1, Class 1
Storage temperature for powder and liquid	60–80°F (15–26°C)
Powder/liquid ratio	21 g (32 cc)/10 mL
Mixing time (time required to wet all particles)	15–30 seconds
Time to reach packing plasticity at 23 ± 1°C	9 ± 2 minutes
Working time	10 ± 4 minutes
Material used to prepare mold	Gypsum
Temperature of mold when packing	Room temperature to 110°F (43°C)
Recommended cure time and temperature	
First stage	1 ½ hours at 163°F (72°C)
Second stage	½ hour at 212°F (100°C)
Alternate cure time and temperature	
First stage	9 hours at 163°F (72°C)
Second stage	½ hour at 212°F (100°C)
Method of cooling flask, time and temperature	
First stage	½ hour in air at 60–80°F (15–26°C)
Second stage	¼ hour in water at 60–80°F (15–26°C)

Note: From Directions for Use, Lucitone 199

Acrylic resin has been reported to have a linear contraction of approximately 0.1%–0.15% (Dixon and others 1992). Because this prosthesis was so large, it was decided to process only two cylinders into the prosthesis. The chosen cylinders were those that were to be attached to the pre-existing osseointegrated implants in tooth sites #22 and 27 (Figures 6.98 and 6.99). The clinical plan was to place all of the implants with the surgical guide, remove the surgical guide, and then place the abutments. After the abutments were in place, the prosthesis would be screwed into the preexisting osseointegrated implants. The prosthesis would be evaluated to make sure that no other abutments or cylinders touched the provisional prosthesis. Then, autopolymerizing acrylic resin would be added to the prosthesis, in effect picking up the cylinders to include all of the cylinders into the prosthesis.



Figure 6.96. Laboratory image of the mandibular provisional prosthesis after processing. A minimal vertical processing error was noted and corrected.



Figure 6.97. Left lateral laboratory image of the mandibular provisional prosthesis after processing. A minimal vertical processing error was noted and corrected.

The mandibular provisional prosthesis, abutments, cylinders, and screws were packaged for shipping. An itemized list was written for the clinicians that identified the specific components for each specific implant (Figure 6.100). The case was shipped to the clinicians prior to the surgical/prosthetic appointment.

SURGICAL IMPLANT PLACEMENT

The surgeon injected an appropriate amount of local anesthetic into the right and left mandibular segments. He placed the surgical guide and went through the specific sequence for each implant site per the surgical



Figure 6.98. Laboratory image of the intaglio surface of the mandibular provisional prosthesis after processing. Only two cylinders were processed into the provisional prosthesis. The other cylinders would be picked up clinically, after implant placement, with autopolymerizing acrylic resin.



Figure 6.99. Laboratory image of the intaglio surface of the mandibular provisional prosthesis after processing. The intaglio surface of the prosthesis was finished with convex surfaces for ease of oral hygiene procedures.

plan provided by the guide manufacturer (Figures 6.101–6.104).

The surgical portion of the treatment was completed, and the implants were considered to be in the positions that had been established in the master cast and the surgical guide (Figures 6.105 and 6.106).

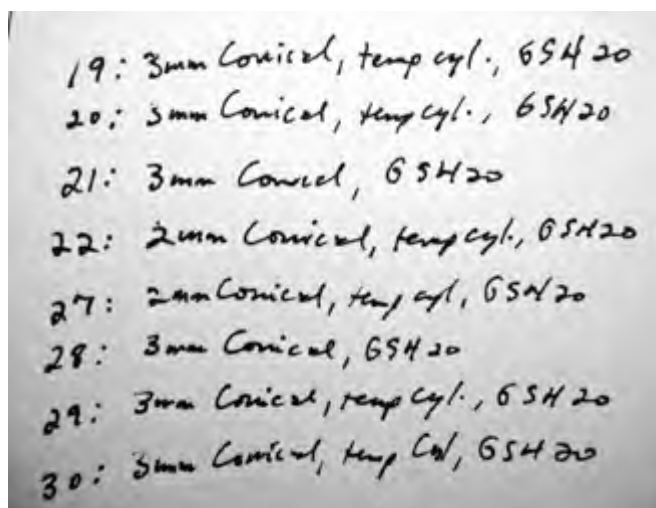


Figure 6.100. This is the handwritten note from the dental laboratory to the clinicians that identified the specific implant components for each of the implants.



Figure 6.101. Surgical image of the tissue punch in the surgical guide. The tissue punch was the first drill in each sequence and removed the soft tissue from the implant sites. Illustration of a tissue punch going to place (upper right inset).

CLINICAL ABUTMENT PLACEMENT

Each specific conical abutment was placed into each specific implant as designated on the treatment plan (Figures 6.107 and 6.108). Each abutment was pressed into place until the click was felt and heard for each implant/abutment connection. The conical abutment screws were threaded into the implants using the abut-

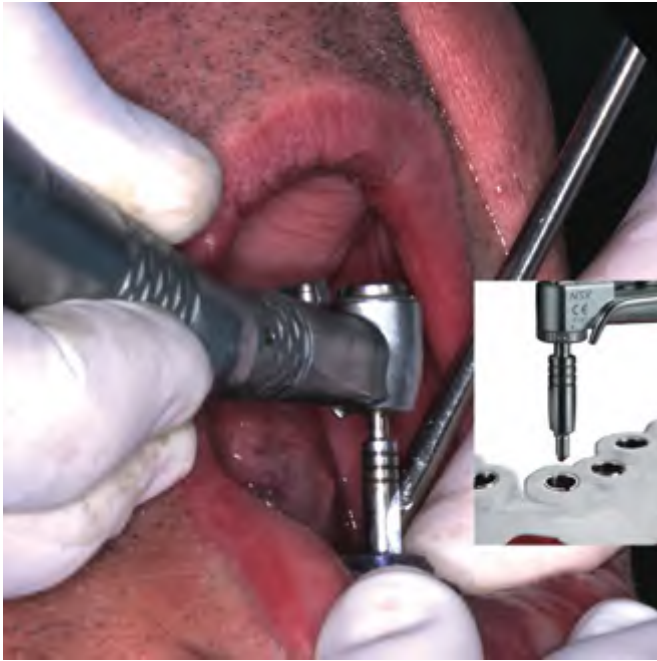


Figure 6.102. Surgical image of the pilot drill in the surgical guide. The pilot drill was used to perforate the cortical crestal bone in each implant site. Illustration of a starter drill going to place (middle right inset).



Figure 6.104. Surgical image of the 2-mm twist drill in place within the 2-mm drill handle. The surgeon will seat the drill completely into the master tube. The drill length was predetermined in the treatment plan. The drill cannot go deeper than planned because of the machined drill stop in the shank, as a metal flange has been machined into the drill shaft to preclude it from going deeper than intended.

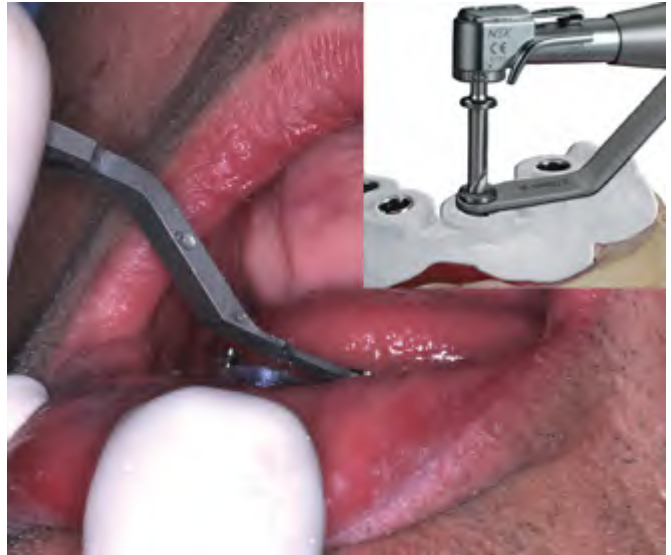


Figure 6.103. Surgical image of the drill handle in place in the surgical guide. This drill handle was designed for use with the 2-mm twist drill. The drill handle changed the diameter of the 4-mm master tube to 2-mm for the 2-mm twist drill. If the drill handle was not used, the surgeon would not be able to put the 2-mm twist drill concentrically within the master tube, and the location of the osteotomy would not be consistent with the planned location. Illustration of a 2.75-mm twist drill in place, in a 2.75-mm drill handle, within the 4-mm diameter master tube (upper right inset).



Figure 6.105. Clinical image of the surgical guide in place after all of the implants had been placed. The implant mounts are visible within the occlusal surface of the surgical guide.



Figure 6.106. Representative illustration of the occlusal surface of this patient's edentulous mandible after removal of the surgical guide. Since the procedure was flapless, there was a minimal amount of blood in the surgical field. The two posterior implants on either side were 5-mm-diameter implants; the remaining six implants were 4.1-mm-diameter implants.

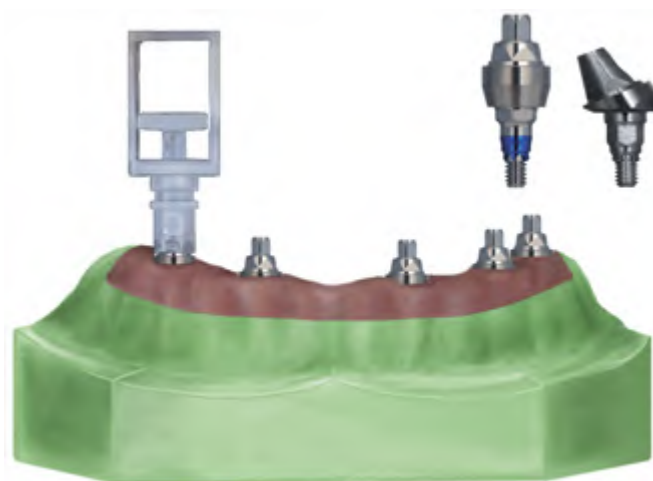


Figure 6.107. Illustration of conical abutments in place on implants that were just placed. The ASYST abutment placement instrument (Biomet 3i) is in place on the right posterior implant. Once the abutment is seated, the plastic thumbscrew is turned until the abutment screw is finger tight. The instrument is then removed, and the abutment screw may be torqued to the correct preload. Straight and 17-degree preangled abutments are in the upper right corner of the illustration.

ment driver. The abutment screws were torqued to 20 Ncm with an abutment driver tip and torque device.

Conical abutment, multiunit temporary cylinders (CC300) were placed onto each abutment of the recently placed



Figure 6.108. Clinical image of the patient with all of the conical abutments in place. No angle corrections were needed; all of the abutments were straight, with varying collar heights.



Figure 6.109. Illustration of a patient with conical abutments and temporary cylinders in place, consistent with the treatment in this chapter. In this clinical illustration, the third implant from the left had the temporary cylinder already processed into the provisional prosthesis. The conical abutment temporary cylinder (CC300) is in the upper left corner of the image.

implants (Figure 6.109). Temporary cylinders were not placed onto the abutments in the osseointegrated implants (tooth sites #22 and 27) because temporary cylinders had already been processed into the prosthesis (Figure 6.110). Waxing screws were used to retain each cylinder to each abutment, except for the two osseointegrated implants. Here, so as not to interfere with the occlusion, retaining screws (GSH30, Biomet 3i) were used. The provisional prosthesis was screwed into the osseointegrated implants (tooth sites #22 and 27), and adjustments were made to the openings so that none of the temporary cylinders touched the provisional prosthesis. The heights of the occlusal surfaces of the artificial teeth were marked on the temporary cylinders with a sterile marker. The waxing screws and temporary cylinders were removed. The occlusion was adjusted for even occlusal contacts throughout the prosthesis. The prosthesis was removed. The cylinders were sectioned just short of the above marks with a separating disk and placed back onto the abutments with the waxing screws (Figure 6.111).



Figure 6.110. Laboratory image of the intaglio surface of the provisional prosthesis prior to the clinical try-in. Since two implants in the cuspid positions were previously placed and already osseointegrated, the temporary cylinders for these abutments were processed into the prosthesis. The other temporary cylinders were going to be picked up clinically.



Figure 6.112. Clinical image with the provisional prosthesis in place. The brush was used to adapt the acrylic resin around the occlusal aspects of the temporary cylinders and the waxing screws. The three-dimensional position of the prosthesis was maintained by the processed temporary cylinders on the abutments that were screwed into the osseointegrated implants.



Figure 6.111. Clinical image of the patient with the temporary cylinders and abutments in place. The temporary cylinders were retained by waxing screws and were adjusted outside the mouth according to the levels of the occlusal surfaces of the denture teeth. Implants in tooth sites #22 and 27 (third from the left and from the right, respectively) did not have temporary cylinders because the cylinders had already been processed into the provisional prosthesis.

INSERTION OF PROVISIONAL PROSTHESIS

The prosthesis was screwed into both the integrated and recently placed implants with waxing screws. Autopolymerizing acrylic resin (Jet Acrylic, Land Dental Manufacturing Co., Inc.) was mixed in two batches. The

first batch was injected into the areas of the prosthesis corresponding to each conical abutment/temporary cylinder; the second batch was injected intraorally around the temporary cylinders. Occlusion was not an issue since the prosthesis was already fitted to the two implants that were already integrated and the prosthesis was retained to the previously integrated implants. A brush was used to adapt the resin in and around the cylinders and waxing screws (Figure 6.112). The acrylic resin was allowed to set, and the prosthesis was removed.

Conical abutment polishing protectors (PPCA3, Biomet 3i) were placed into the temporary abutment cylinders with the waxing screws; additional acrylic resin was added for optimal emergence profiles (Figure 6.113). The prosthesis was polished (Figure 6.114) and reinserted clinically. Retaining screws (GSH30) were torqued to 10Ncm with a torque instrument. The access openings were restored with cotton and light-cured composite resin (Figures 6.115–6.117).

The patient was given postoperative instructions that included nonsteroidal anti-inflammatory medications and a soft diet. Oral hygiene instructions were deferred until the 24-hour postoperative visit. The patient was extremely pleased with the aesthetic results and was discharged in excellent condition.



Figure 6.113. Intaglio image of the provisional prosthesis after the initial application of acrylic resin. Additional acrylic resin was needed on several of the temporary cylinders. Polishing protectors (PPCA3; center inset), consistent with the implant restorative components, should always be used when applying resin and during any polishing procedures. This ensures that the integrity of the temporary cylinder/abutment connections will be maintained.



Figure 6.114. Occlusal surface of the provisional prosthesis after polishing.

POSTOPERATIVE VISIT

The patient returned in 2 days for the first postoperative visit. He and his spouse were extremely pleased with the aesthetic results, and he reported absolutely no postoperative discomfort. The occlusion was evaluated and found to be consistent with the insertion appointment. Oral hygiene instructions were given, which included flossing demonstrations. He was discharged and asked to return in 1 month.

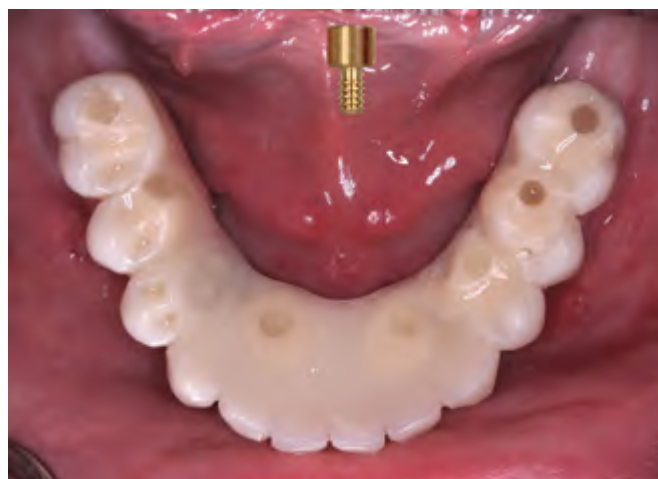


Figure 6.115. Clinical occlusal image of the provisional prosthesis after insertion. The cylinders of the prosthesis were retained to the abutments with retaining screws (GSH30; center inset). The screws were torqued to 10 Ncm with a torque instrument. The access openings were restored with cotton and light-cured composite resin.



Figure 6.116. Left buccal clinical image of the provisional prosthesis in place. The prosthesis was contoured so that oral hygiene procedures could be accomplished with relative ease. The spaces between the intaglio surface of the prosthesis and the peri-implant soft tissues did not affect phonetics or aesthetics.



Figure 6.117. Right buccal clinical image of the provisional prosthesis in place. The prosthesis was contoured so that oral hygiene procedures could be accomplished with relative ease. The spaces between the intaglio surface of the prosthesis and the peri-implant soft tissues did not affect phonetics or aesthetics.

The following clinicians and dental laboratory technicians were responsible for the treatments illustrated in this chapter:

Implant Surgeon: Dr. Robert del Castillo, Miami Lakes, FL

Prosthodontist: Dr. Carl Drago, Jupiter, FL

Dental Laboratory Technicians: Thomas Peterson, MDT, CDT; Alexey Zorin, North Shore Dental Laboratories, Lynn, MA

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Chapter 7: Three-Unit Implant-Retained Porcelain-Fused-to-Metal Fixed Partial Denture with Premachined, Fixed Collar Height Titanium Abutments

INTRODUCTION

Clinicians face a tremendous challenge in selecting abutments for implant restorations. Binon reported in 2000 that in the United States alone, there were more than 1300 implants and 1500 abutments from which to choose. Abutments are the portions of the implant restoration that support or retain the prosthesis or implant framework (Glossary of Prosthodontic Terms 2005).

There are four types of abutments available for single- or multiple-unit implant crown restorations:

1. Stock, premachined metal or ceramic abutments whose margins may be adapted to follow gingival architecture
2. Stock, premachined metal or ceramic abutments with fixed gingival margins
3. Custom cast abutments
4. Computer-aided design/computer-aided manufacturing (CAD/CAM) metal or ceramic abutments

This chapter will illustrate the benefits and limitations of stock, premachined titanium abutments (Provide® Abutment Restorative System, Biomet 3i, Palm Beach Gardens, FL) as retainers for a three-unit fixed partial denture (FPD) in the mandibular right posterior quadrant (Figure 7.1).

Provide Abutments are available for 4.1-, 5- and 6-mm implant restorative platforms. They are machined with post heights of 4 or 5.5 mm; collar heights of 1, 2, 3, and 4 mm; and with the Osseotite® Certain® internal implant connection (Biomet 3i) (Figures 7.2 and 7.3). They are indicated for use with single- and multiunit crown restorations where the gingival margins are flat and not scalloped (Figure 7.4). The maximum angle correction for this abutment system is 10 degrees, and the minimum interarch space is 6 mm. This abutment system also features snap-on impression components (Figure 7.5).

Typically, the implant surgeon places this type of abutment prior to discharging the patient to the restorative dentist for the implant restoration. The decision to use this type of abutment should have been discussed by the surgeon and

the restorative dentist at one of the treatment planning conferences preoperatively.

The surgeon selects the correct abutment by first measuring the greatest height of the healing abutment above the buccal peri-implant gingival margins. Generally, this is in the midfacial portion of the implant site. This does not include the dome portion of the healing abutment (Figure 7.6). This number is subtracted from the height of the healing abutment, and an additional 1 mm may be subtracted if the clinician desires subgingival margins for the abutment. One of the major disadvantages of fixed margin abutments is that the margins may be optimal in one or two areas but may be too deep or too shallow in other areas. One of the contraindications for fixed margin abutments is a high, scalloped gingival architecture.

The healing abutment is removed from the implant using the 0.048-in. large hex driver (Figure 7.7). The fingers of the selected Provide Abutment are activated with the QuickSeat® Activator Tool (Biomet 3i), and the Provide Abutment is seated into the implant/abutment connection (Figures 7.8 and 7.9). The clinician should feel and hear the tactile and audible click. This initial try-in should be accomplished with a try-in screw (IUNITS, Biomet 3i), and a verification radiograph should be made. The radiograph is necessary to ensure that the abutment is completely seated prior to torquing the definitive abutment screw and discharging the patient to the restorative dentist. After complete abutment seating has been verified, the try-in screw should be removed and replaced with the definitive abutment screw. The abutment screw (Certain® Gold-Tite® Abutment Screw, Biomet 3i) is threaded into place and torqued to 20 Ncm using a 0.048-in. large hex driver tip and a torque device (Figure 7.10). The implant surgeon may or may not place a protection cap onto the abutment to protect the patient's tongue from the abutment. The implant surgeon then discharges the patient to the restorative dentist for restoration of the implant.

This system is complemented with a full set of laboratory components, including laboratory analogs (Figure 7.11), waxing sleeves (Figure 7.12), and temporary cylinders (Figure 7.13). The laboratory analogs are color coded to fit into similarly colored snap-on impression copings. The Provide Abutments are available for purchase as two



Figure 7.1. Provide Abutments with 1-, 2-, 3- and 4-mm collar heights for 4.1-mm implant restorative platforms. All of these abutments have 4-mm post heights. Catalog numbers are beneath each component.



Figure 7.2. Provide Abutments with 2-mm collar heights; 4-mm post height (left); 5.5-mm post height (right).



Figure 7.3. Provide Abutment with 4.1-mm implant restorative connection; 2-mm collar height and 4-mm post height.



Figure 7.4. Master cast with flat gingival margins in the posterior, nonaesthetic zone of a right maxilla. This would be an ideal place to use fixed margin abutments.



Figure 7.5. Snap-on impression copings are colored coded for use with Provide Abutments. They snap into place onto the abutments and are removed with the impression. They should be used with a closed-tray technique. Catalog numbers are beneath each component.



Figure 7.6. Illustration of a periodontal probe in place at the crest of the peri-implant soft tissues. In this instance, the 4-mm tall healing abutment extends 3 mm supragingival; the subgingival portion of the healing abutment measures 1 mm. Depending on the aesthetic demands of the patient, a 1- or 2-mm collar height Provide Abutment may be selected.



Figure 7.7. Illustration that depicts removal of the healing abutment with a large hex driver (0.048 in.) (PHD02, Biomet 3i).



Figure 7.9. Illustration of the clinical procedure to place the abutment into the implant intraorally. The hexes of the implant/abutment connection need to be aligned prior to pressing the implant into place apically. The clinician should hear and feel the audible and tactile clicks, verifying that the abutment is completely seated into the implant. The try-in screw (IUNITS) is on the left side of the image.



Figure 7.11. Provide Abutment laboratory analogs with 4.8-mm emergence profile, 4-mm post height (PAA484); 4.8-mm emergence profile, 5.5-mm post height (PAA485); 6.5-mm emergence profile, 4-mm post height (PAA654); 6.5-mm emergence profile, 5.5-mm post height (PAA655) (left to right).



Figure 7.8. Illustration that demonstrates activation of the fingers of a Provide Abutment. The fingers are responsible for the audible and tactile clicks noted upon insertion of the abutment into an analog or implant.



Figure 7.10. Illustration of abutment screw (IUNIHG; upper left inset) threaded into place with the same large hex driver that was used to remove the healing abutment (PHD02) (IUNIHG and PHD02, Biomet 3i, Palm Beach Gardens, FL).



Figure 7.12. Provide Abutment waxing sleeves: multiunit (PWS48M; left); single unit (PWS48S; right). These two components are manufactured for use with Provide Abutments with 4.8- or 6.5-mm emergence profiles and 4- or 5.5-mm post heights.



Figure 7.13. Provide Abutment temporary cylinders: single unit (PUA65S; left); multiunit (PUA65M; right). These two components are manufactured for use with Provide Abutments with 4.8- or 6.5-mm emergence profiles and 4- or 5.5-mm post heights.



Figure 7.14. Provide Abutment Placement Kit (PAK4440): 4.8-mm emergence profile, 4-mm post height (IPA4440); abutment screw (IUNIHG); protection cap (PPC484) (left to right).

different types of kits: surgical (placement) and restorative (Figures 7.14 and 7.15).

CLINICAL PATIENT PRESENTATION

A 62-year-old patient present to the author with a chief complaint, “My teeth hurt in the lower right area.” The patient had complained of nonspecific pain that seemed to localize around teeth #28 and 30 (Figure 7.16).

DIAGNOSIS

The following diagnoses were made:

1. Recurrent caries distal surfaces of teeth #28 and 30
2. Chronic pulpitis in teeth #28 and 30
3. Adequate bone volume for implant placement in the mandibular right quadrant
4. Adequate restorative volume for implant restorations in the mandibular right quadrant



Figure 7.15. Provide Abutment Restorative Kit (PRK484): abutment analog for Provide Abutment (IPA4440); impression coping (PIC484); impression coping if abutment was prepared (PIC484H); waxing sleeve (PWS48S; top); temporary cylinder-single unit (PUA48S; bottom) (left to right).

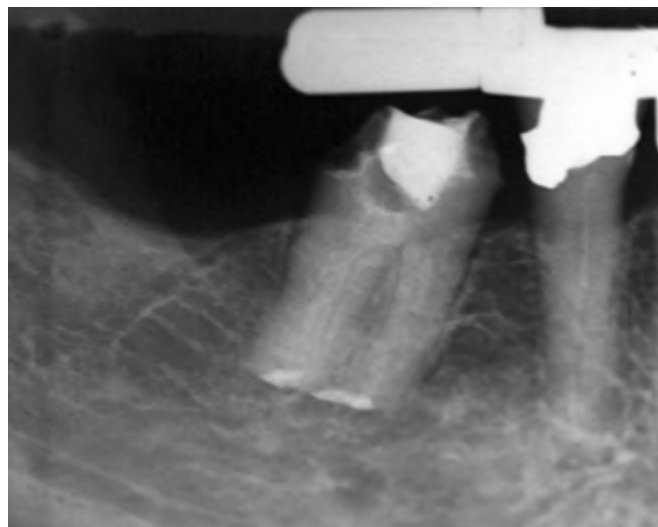


Figure 7.16. Preoperative periapical radiograph of teeth #28 and 30. There are distal caries noted for both teeth. If the teeth were to be salvaged, endodontics, clinical crown lengthening, post and cores, and new crown restorations would be indicated.

ASSESSMENT

The mandibular right first premolar and first molar could be retained if the patient wished to undergo endodontic treatment for both teeth and then have periodontal surgery in the mandibular right quadrant to uncover the tooth margins and provide for a physiological biological width



Figure 7.17. Laboratory occlusal view of mandibular diagnostic cast.

for both teeth. The definitive restorations would then consist of post and cores and new crowns. The above procedures would be expensive to perform, and the patient would still be left with teeth with compromised long-term prognoses. Another alternative that was presented involved extraction of the two involved teeth, followed by osseous healing and then placement of implants to retain abutments for an implant-retained, three-unit FPD. After discussing the benefits and limitations of both of the above treatments, the patient elected to proceed with extractions followed by implant placement.

ABUTMENT SELECTION

Abutment selection for dental implants should be accomplished at the treatment planning stage. Implant surgeons, restorative dentists, and dental laboratory technicians should be involved in this process. The abutment selection process should include the following criteria (Lazzara and Drago 2009):

1. Implant/abutment connection (internal/external)
2. Implant restorative platform (diameter in millimeter)
3. Emergence profile of the interim abutment or healing abutment (diameter in millimeter)
4. Angulation of the implants (buccal/lingual; mesial/distal)
5. Soft tissue depth (in millimeter)
6. Interocclusal distance (in millimeter)

Since the implants were located in a nonaesthetic zone (the mandibular right posterior quadrant) and only the

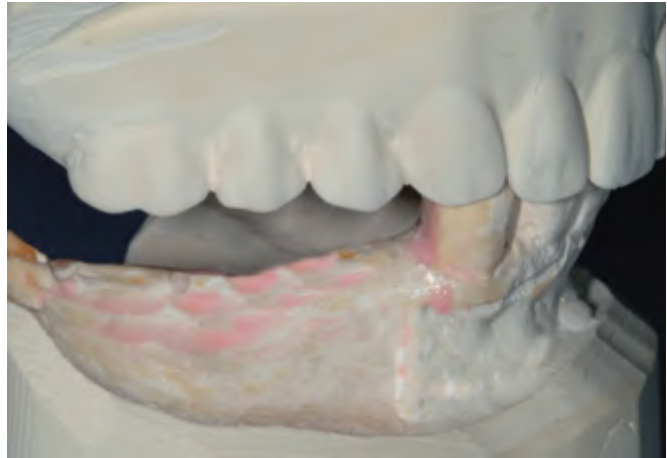


Figure 7.18. Laboratory view of mounted maxillary and mandibular diagnostic casts that demonstrates the lack of a gingival scallop in the right mandibular posterior quadrant and the adequate interocclusal clearance for the implant-retained fixed partial denture.

mesial implant had an adjacent tooth, the implant team decided on fixed margin type abutments (Figure 7.17). The distal implant was planned for a 5-mm-diameter implant; the anterior implant was planned for a 4-mm-diameter implant. The ideal prosthetic locations for both implants would be determined from the diagnostic wax patterns.

DIAGNOSTICS

Diagnostic casts were fabricated from conventional alginate impressions and poured in dental stone. They were mounted in centric occlusion in a simple hinge articulator (Hanau Mate, Waterpik Technologies, Fort Collins, CO) (Figure 7.18). Denture teeth were used instead of waxing three individual wax patterns. The denture teeth and wax determined the optimal prosthetic positions of the teeth on the implant-retained prosthesis (Figure 7.19). A surgical guide was made that included several teeth anterior to the proposed implant sites (Figure 7.20).

SURGERY

Two implants were placed in a two-stage surgical protocol (Figure 7.21). The incised soft tissues were closed primarily over the cover screws of the implants, and the implants were allowed to heal without occlusal loading.

Osseointegration occurred uneventfully, and the surgeon decided to make small incisions and place the Provide Abutments at the time the implants were uncovered (Figures 7.22 and 7.23; Table 7.1). The abutment screws were torqued to 20Ncm with a torque driver, and the



Figure 7.19. Denture teeth were used as the diagnostic patterns in order to optimally locate the prosthetic positions of the teeth within the implant-retained FPD.



Figure 7.20. The surgical guide was made directly on the diagnostic cast with the denture teeth in place.

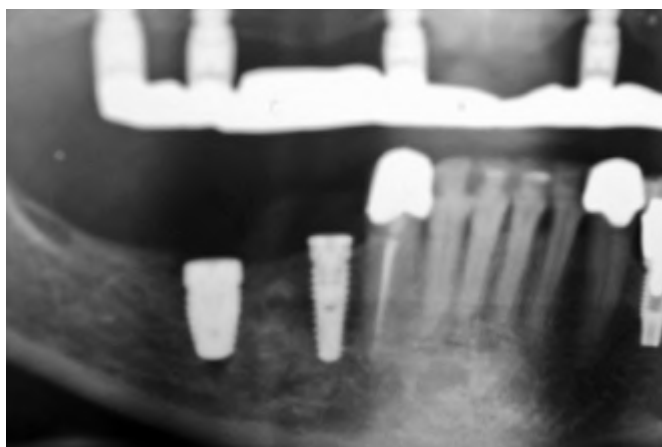


Figure 7.21. Panoramic radiograph that was made immediately after the implants were placed. Even though a 5-mm-diameter implant was originally called for in the molar area, a 6-mm-diameter implant was placed because it obtained primary stability, whereas the 5-mm-diameter implant did not.



Figure 7.22. Clinical buccal view of the Provide Abutments in place at the time of the second surgery. The flat sides of the abutments were placed on the mesial aspects of the implants to maintain optimum retention and resistance form of the abutments.



Figure 7.23. Clinical lingual view of the abutments in place at the time of the second surgery. A small amount of hemorrhage was visible around both abutments. Note that the mesial margin of the anterior abutment is slightly more subgingival than the other margins of the abutment.

implant surgeon, with the aid of the dental laboratory technician, proceeded to make a provisional FPD.

Note that the mesial margin of the anterior abutment is slightly more subgingival than the other margins of the abutment. This is one of the major disadvantages of fixed margin abutments, in that secondary to the location of the gingival margins, some sections of the margins may be optimally placed relative to the gingival contours. Other sections may be located supra- or subgingival, contrary to the clinicians' wishes.

TABLE 7.1. Provide Abutments Used in This Case

Tooth #	Emergence Profile (mm)	Collar Height (mm)	Post Height (mm)	Catalog Number
28	4.8	3	5.5	IPA4355
30	6.5	2	4	IPA6240



Figure 7.24. Polyvinyl siloxane putty was used to make a mold of the diagnostic wax patterns (denture teeth) on the mandibular diagnostic cast. This material is preferred by the authors as it does not create heat during polymerization and can be used directly on wax patterns.

In order to provide the patient with occlusal function at the time the implants were uncovered, a mold for a provisional three-unit FPD was fabricated in the laboratory and the prosthesis would be relined clinically. A silicone mold (Imprint™ 3 Penta™ Putty Impression Material, 3M Co., St. Paul, MN) was made on the diagnostic cast with the denture teeth in place (Figure 7.24). Silicone is preferred since it does not generate heat with polymerization.

Provide Abutment Temporary Cylinders (PUA48M for the premolar implant; PUA65M for the molar implant) were placed onto the abutments clinically (Figure 7.25). A bis-acryl resin (Zenith/DMG Luxatemp®, Zenith Dental, Englewood, NJ) was mixed, injected into the mold by the dental laboratory technician, and handed to the implant surgeon, who placed the mold and resin onto the abutments in the mouth (Figure 7.26). The material reached its initial set approximately 1 minute after the mold was inserted into the mouth. The mold and provisional restoration was removed. The temporary cylinders were picked up inside the provisional prosthesis; the prosthesis was allowed to completely polymerize (Figure 7.27). The provisional prosthesis was trimmed and polished (Figures



Figure 7.25. Temporary cylinders such as these were placed onto the abutments in the mouth, prior to fabricating the provisional FPD. Temporary cylinders are available from the manufacturer for both single- and multiple-unit cases. In this instance, the multiunit cylinders were used (left).



Figure 7.26. The provisional material was injected into the silicone mold of Figure 7.24 by the dental laboratory technician and handed to the implant surgeon.

7.28 and 7.29). The provisional prosthesis was cemented to the abutments with temporary cement (Figure 7.30).

The patient was discharged with oral hygiene instructions and minimal dietary restrictions until resolution of the local anesthetic had occurred. She was reappointed to return



Figure 7.27. After the resin had reached its initial set intraorally, the silicone mold and prosthesis were removed from the mouth. The prosthesis was removed from the silicone mold and allowed to completely polymerize.



Figure 7.29. Laboratory intaglio view of the provisional prosthesis after trimming and polishing procedures were accomplished. The temporary cylinders dramatically improved the fit of the resin prosthesis to the abutments, which resulted in minimal postoperative adjustments for the restorative dentist.



Figure 7.28. Laboratory occlusal view of the provisional prosthesis after trimming and polishing were accomplished.

for the definitive impression of the abutments at the restorative dentist's office in 4 weeks.

ABUTMENT IMPRESSION

Impression trays can be either stock or custom made for each particular patient. If stock impression trays are used, the clinician must be sure that the tray is rigid and strong enough to resist distortion upon removal from the mouth. Trays should be rigid but not overly thick and should maintain their shapes throughout the construction and pouring of the impression (Rudd and Morrow 1980).

In a laboratory study, Naconecy and others (2004) evaluated the deformation of a metallic framework connected to 15 stone casts fabricated with three transfer impression techniques. Custom acrylic resin trays were used for all of the impressions. They were trying to determine the most accurate impression procedure for implant restor-



Figure 7.30. Clinical buccal view of the provisional prosthesis in place, post cementation with temporary cement. The margins of the anterior retainer were supragingival; the margins of the posterior retainer were at the level of the gingival crest. The inset is an illustration of an acrylic resin crown attached to single-unit Provide Temporary Cylinder.

ative dentistry. Five stone casts were made from polyether impressions of an epoxy resin master model for three different transfer impression techniques in custom trays. They concluded that the direct splinted technique was the most accurate transfer method for multiple abutments compared with direct nonsplinted and indirect techniques.

Kim and others (2006) also performed a laboratory study that compared the accuracy of different impression techniques. Two techniques for impressions were assessed: a nonsplinted open-tray technique and a light-cured resin

splinted open-tray technique. A mandibular model with five parallel implants was fabricated. Five definitive casts were fabricated with each technique. The average displacements that were recorded with splinted impression copings and abutment replicas were 31.3 and 30.4 μm , respectively. Less displacement occurred in the nonsplinted group compared with the splinted group during impression making ($P = 0.001$), but greater displacement occurred in that group during definitive cast fabrication ($P = 0.015$). In contrast to previously reported studies, Kim and others (2006) excluded displacement resulting from component connection because displacement from that source had no relation to impression technique and could not be controlled. Kim and others (2006) concluded that connecting a component produced as great a displacement as that resulting solely from a impression or cast fabrication. The nonsplinted group was more accurate during impression making but less accurate during cast fabrication.

In this case, the patient returned approximately 4 weeks after the above surgery for the definitive impression. The provisional FPD was removed and the abutments were visualized. The appropriate abutment impression copings were placed onto each abutment. Provide impression copings are designed to snap into place after aligning the flat surfaces of the abutments to the flat inner surfaces of the impression copings (Figure 7.31). The impression copings for this implant restorative system are color coded to fit the abutments relative to the post heights and restorative diameters (see Figure 7.5). In this case, impression coping (catalog # PIC654) was selected for use with the posterior molar abutment (catalog # IPA6240). Impression coping (catalog # PIC485) was selected for the anterior premolar abutment (catalog # IPA4355) (Table 7.2; Figure



Figure 7.31. Provide impression copings are designed to snap into place after the flat surfaces of the abutments and impression copings are aligned. In this illustration, the flat surface of a Provide Abutment and the flat surface of the impression coping were aligned, prior to snapping the impression coping into its proper position on the abutment.

7.32). The definitive impression was made with polyvinyl siloxane impression material in a stock plastic tray. Both impression copings were picked up in the impression (Figure 7.33).

MASTER CAST WITH ABUTMENT ANALOGS

Using the appropriate, color-coded Provide Analogs that matched the colors of the impression copings, the flat sides of the analog posts were aligned with the flat sides

TABLE 7.2. Provide Impression Copings Used in This Case

Tooth #	Catalog Number
28	PIC485
30	PIC654



Figure 7.32. Plastic pick-up impression copings in place on the Provide Abutments (catalog # PIC654, molar; catalog # PIC485, premolar).



Figure 7.33. Intaglio surface of the definitive impression with both impression copings in place.



Figure 7.34. Abutment analogs were placed into the impression copings contained within the impression. The flat sides of the impression copings lined up with the flat sides of the analogs. Insets illustrate the intimate fit between the impression copings and abutment analogs.



Figure 7.35. Mandibular master cast with abutment analogs in place.

of the impression copings and the analogs were snapped into place (Figure 7.34). Polyvinyl siloxane impression material was injected around the impression coping/analog interfaces to simulate the peri-implant soft tissues clinically. The cast was poured with type IV dental stone (GC Fujirock® EP, GC America Inc., Alsip, IL) (Figure 7.35). The mandibular cast was articulated against the maxillary diagnostic cast on a semiadjustable articulator (Hanau 96H2O, Whip Mix Corp., Louisville, KY) (Figure 7.36).

WAXING SLEEVES

Waxing sleeves are provided as part of the Provide Restorative Kits. The sleeves are coordinated with the spe-



Figure 7.36. Buccal view of the maxillary and mandibular casts mounted on a semiadjustable articulator. Adequate interocclusal clearance was evident between the occlusal aspects of the abutments and the occlusal surfaces of the opposing dentition in anticipation of the planned three-unit fixed partial denture.

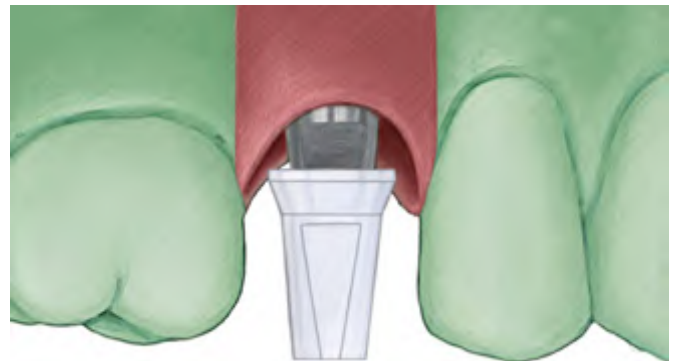


Figure 7.37. Illustration of a waxing sleeve going to place over a single Provide Abutment. For single units, the flat side of the abutment is aligned with the flat side of the waxing sleeve.

cific sizes of the abutment analogs. Waxing sleeves are used to provide an intimate fit between the castings and the abutment analogs and abutments (Figure 7.37). Two layers of die spacer have been provided within the waxing sleeves; therefore, no further die spacer is needed. For single units, the flat surfaces of the waxing sleeves are aligned with the flat surfaces of the abutment analogs. Multiple-unit waxing sleeves do not have the flat surface antirotation feature (Figure 7.38).

Buccal and lingual silicone indexes were made of the wax patterns (denture teeth) (Figure 7.39). With the silicone



Figure 7.38. Multiunit waxing sleeve, without flat surface antirotation feature (left); single-unit waxing sleeve, with flat surface antirotation feature (right).



Figure 7.39. Buccal and lingual silicone molds were made of the diagnostic denture teeth setup to simplify waxing the definitive fixed partial denture to full contour. This is a laboratory occlusal view of the two indexes in place, surrounding the denture teeth in the original diagnostic setup.

indexes in place, the FPD was waxed to full contour directly to the waxing sleeves. The wax was cut back to provide optimal contours and strength for the metal framework and to provide adequate room for the porcelain ceramic (Scortecchi 2001) (Figure 7.40).

The wax pattern was invested in phosphate-bonded investment (Power Cast, Whip Mix Corp.). This is a carbon-free, fine-grain phosphate investment for casting crown and bridge and ceramic alloys. This investment has been formulated to use with a rapid burnout technique. Power Plus Liquid (Whip Mix Corp.) provides the high expansion especially needed for nonprecious alloys and can be diluted as needed for other alloys. Whip Mix Corp. has stated that the investment is crack resistant and tolerates a rapid

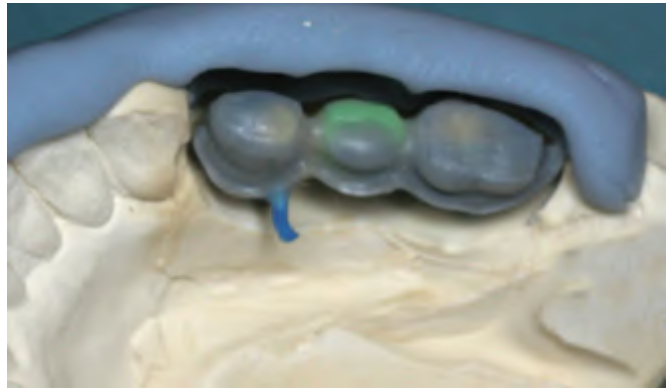


Figure 7.40. Laboratory occlusal view of the wax pattern for the FPD after it had been cut back to provide for the porcelain ceramic material in the definitive prosthesis. The silicone index provided visual reference points to insure adequate clearance was obtained between the metal framework and ceramic material in the definitive prosthesis.

TABLE 7.3. Physical Properties of Power Cast Investment

Physical Properties

Liquid*/powder ratio	23mL/100 g
Working time	8–9 minutes
Setting expansion	0.8%
Thermal expansion	1.0%
Compressive strength (wet)	700psi (5MPa)

*Suggested concentration of Power Plus Liquid is 80% (4 parts liquid to 1 part water).

temperature rise. Power Cast produces smooth, accurate castings with reduced finishing time (Table 7.3).

The investment was mixed with 90 g of powder and 21 mL of Power Plus liquid. The liquid was measured first and placed into a dry bowl, followed by adding the weighed powder. This was hand mixed for 20 seconds and then mechanically mixed under vacuum at 350–400rpm for approximately 90 seconds. For the ringless technique, the investment set for approximately 25 minutes, and then the ring and base were removed. The investment set for an additional 25 minutes prior to placing it into the oven. The mold was placed into a preheated oven at 700–850°C (1300–1550°F). The mold was held at this temperature for 30–40 minutes and cast with a gold/palladium alloy (Table 7.4).

DEFINITIVE PROSTHESIS

The investment was removed from the casting, and the casting was prepared for porcelain (Figures 7.41–7.43).

TABLE 7.4. Physical Properties of Olympia Alloy (Jelenko, San Diego, CA)

Composition	%
Gold	51.5
Palladium	38.4
Indium	8.5
Gallium	1.5
Ruthenium	<1
Physical Properties	
Casting temperature	2552°F (1400°C)
Melting range	2228–2462°F (1220–1350°C)
Density (g/cc)	13.7
Vickers hardness	255
Ultimate tensile strength	115,000 psi (793 MPa)
Yield strength (.2%)	80,000 psi (551 MPa)
Modulus of elasticity	18,000,000 psi (124,072 MPa)
Elongation	20%
Thermal expansion ($\times\mu\text{m/m}\cdot\text{K}$)	13.9 at 500°C; 14.2 at 600°C



Figure 7.41. Laboratory view of the facial surfaces of the casting prior to porcelain application.

The porcelain was applied per the manufacturer's instructions (Imagine Reflex, Wieland Dental + Technik GmbH & Co. KG, Pforzheim, Germany) (Figures 7.44–7.48). This porcelain was used because it results in an extremely smooth and homogeneous surface that, according to the manufacturer, is plaque resistant. It also polishes very well clinically after adjustment. Reflex® is characterized by bubble-free opaque and dentin layers. This results in optimal bond strengths to metal copings. Slow cooling is generally not required; Reflex has an above-average bond strength with all of the alloys in the indicated range



Figure 7.42. Laboratory view of the facial surfaces of the casting prior to porcelain application with the soft tissue replica removed.



Figure 7.43. FPD framework with original, preoperative silicone index in place. The space between the framework and the index represents the contours of the preoperative wax patterns and gave the dental ceramist a three-dimensional guide for stacking the porcelain.



Figure 7.44. Buccal image of completed FPD.



Figure 7.45. Intaglio surface of the completed FPD. The pontic tissue surface was contoured for use as an ovoid pontic to give the illusion that the pontic was a natural tooth emerging from the soft tissue in the mandibular right posterior quadrant.



Figure 7.46. Lingual image of the completed FPD. Note that the lingual margins of the retainers are supragingival. This margin design made it easier for the clinician to visually verify that the prosthesis was completely seated onto the abutments. It also made it easier to verify that all of the cement had been removed from the lingual peri-implant sulci.



Figure 7.47. Laboratory occlusal view of completed prosthesis. The prosthesis was ready to be shipped to the clinician.



Figure 7.48. Laboratory buccal view with the prosthesis in centric occlusion against the maxillary cast on the articulator. Group function occlusion was established in the right working movement, and there were no balancing side contacts with the mandible in a left lateral working position.

TABLE 7.5. Physical Characteristics of Reflex Porcelain

Firing temperature: 900°C (first dentin bake)
CTE range of precious alloys: $13.8\text{--}15.1 \cdot 10^{-6}/\text{K}$
(25–500°C)

CTE, coefficient of thermal expansion.

(Table 7.5). Reflex porcelain has an innovative “nanoleucite structure” (Figures 7.49 and 7.50). This is said to result in a crack-free microstructure containing homogeneously distributed, fine leucite crystals. Many of the crystals have dimensions on the nanometer scale ($1\text{ }\mu\text{m} = 1000\text{ nm}$), thus giving their name to the structure.

The prosthesis was returned to the clinician for evaluation and insertion. The clinician evaluated the prosthesis as follows:

1. Overall finish and polish of the porcelain and framework
2. Marginal integrity of the prosthesis on the abutment analogs
3. Emergence profiles of the retainers and pontic
4. Width of the occlusal tables
5. Centric contacts
6. Working side contacts
7. Lack of balancing side contacts



Figure 7.49. Photomicrograph of Reflex porcelain surface that demonstrates the nanosized porcelain crystals (courtesy of Wieland Dental + Technik GmbH & Co. KG).



Figure 7.50. Photomicrograph of conventional porcelain that demonstrates the larger-sized leucite crystals (courtesy of Wieland Dental + Technik GmbH & Co. KG).

INSERTION

In this case, the clinician removed the provisional restoration and noted minimal inflammation in the peri-implant tissues. The prosthesis went to place with minimal adjustments of the interproximal contact (Figure 7.51). A verification radiograph was taken, and the margins of the retainers were noted to fit well (Figure 7.52). The occlusion was evaluated and adjusted to provide even occlusal contacts in the posterior segments, right group function working contacts, and no balancing side or protrusive interferences. The prosthesis was polished and cemented with permanent cement. The patient was pleased with the aesthetic result (Figure 7.53).



Figure 7.51. Clinical buccal view of the prosthesis in place.

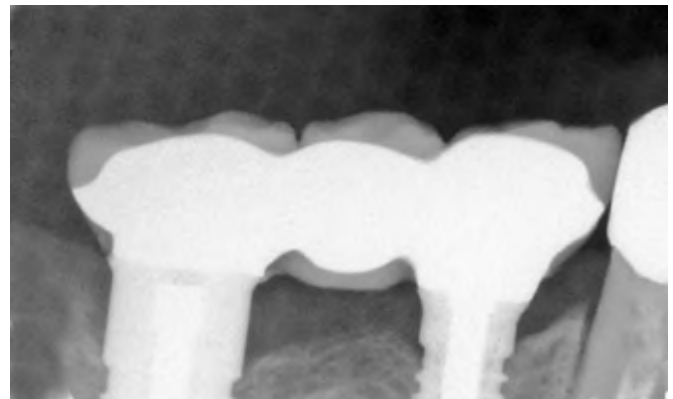


Figure 7.52. Radiograph of the prosthesis in place that demonstrated excellent marginal fit between the retainers and the abutments.



Figure 7.53. Clinical anterior view of the patient in centric occlusion, with the definitive prosthesis in place.

AESTHETIC EVALUATION

Evaluating implant prostheses is usually qualitative in nature. Testori and others (2005) established an “implant aesthetic score” in an attempt to quantify aesthetics in implant restorations. Their paper concentrated on anterior aesthetics and changing implant loading protocols.

However, the criteria represent a quantitative measurement of implant aesthetics and will be used here. They identified and assigned numerical scores in the following five categories:

1. Presence and stability of the mesiodistal papillae
 - a. 0 = papilla
 - b. 1 = does not fill the entire space but is aesthetically acceptable
 - c. 2 = total fill
2. Ridge stability buccopalatally
 - a. 0 = width with ridge loss
 - b. 1 = width maintained
3. Texture of the peri-implant soft tissue
 - a. 0 = complete loss of texture
 - b. 1 = does not look like healthy tissue
 - c. 2 = looks like healthy gingival tissue around natural teeth
4. Color of the peri-implant soft tissue
 - a. 0 = completely different color from healthy tissue
 - b. 1 = does not look like healthy tissue but still aesthetically acceptable
 - c. 2 = looks like healthy tissue around natural teeth
5. Gingival contours
 - a. 0 = evident asymmetry from the accepted parameters of scalloping
 - b. 1 = signs of asymmetry but aesthetically pleasing
 - c. 2 = harmonious gingival contours

Testori and others (2005) related that a score of 9 was equal to a perfect outcome; acceptable outcomes were between 4 and 8; compromised outcomes were between 0 and 3.

In this case, the aesthetic results were quantified as follows:

- | | |
|--------------------|---|
| 1. Papilla | 1 |
| 2. Ridge stability | 1 |

- | | |
|--|---|
| 3. Texture of peri-implant soft tissue | 1 |
| 4. Color of peri-implant soft tissue | 1 |
| 5. Gingival contours | 1 |

The total score equaled 5 and was considered an acceptable outcome.

The following clinicians and dental laboratory technicians were responsible for the treatments illustrated in this chapter:

Implant Surgeon: Dr. Ronald Guttu, Gundersen Lutheran Medical Center, LaCrosse, WI

Prosthodontist: Dr. Carl Drago, Gundersen Lutheran Medical Center, LaCrosse, WI

Dental Laboratory Technician: Thomas Peterson, CDT, MDT; Shawn Vittorioso, Carla Palau North Shore Dental Laboratories, Lynn, MA; and Andrew Gingrasso, Gundersen Lutheran Medical Center, LaCrosse, WI

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Chapter 8: Multiple CAD/CAM Abutments with Implant-Retained Porcelain Metal Crowns (The Encode® Complete Protocol)

INTRODUCTION

Preoperative treatment planning includes selection of appropriate-sized implants in terms of length, diameter, three-dimensional (3-D) locations, and implant/abutment connections. Before any implants are placed, the surgeon must assess the anatomical areas in terms of quantity and quality of bone, location of anatomical landmarks, and the proposed designs of the restorations/prostheses (Figures 8.1 and 8.2).

During the presurgical restorative planning phase, it is critical for the surgeon, restorative dentist, and dental laboratory technician to participate in discussions relative to determining the type of prosthesis and the requisite restorative components that will be used during treatment. These decisions should be finalized prior to surgery. Top-down treatment planning is the term used for this process, whereby the implants and restorative components to be used in a given partially edentulous situation should be determined by the size of the tooth (teeth) being replaced (Lazzara 1989) (Figure 8.3).

The clinical information required for top-down treatment planning includes, but is not limited to:

1. The restorative volume available for the planned restorations, including the vertical distance between the implant restorative platform and the opposing occlusal surfaces
2. The surgical volume of bone available for the planned implant, including the location of specific anatomic structures that may preclude implant placement (inferior alveolar canal, maxillary sinus, nasal floor, etc.)

The height of implant restorations varies with the type of abutment and restoration planned. In areas of limited or excessive interocclusal distance (<5, >10mm), screw-retained crowns may be the treatment of choice (Figure 8.4). By visualizing the design characteristics of the definitive restoration prior to implant surgery, the surgeon, restorative dentist, and dental laboratory technician have the opportunity to identify potential restorative problems such as screw loosening, loss of crown retention, and porcelain fracture. Modifications can be made preoperatively, and treatment predictability can be increased.

Patients have long desired fixed restorations for missing teeth (de Bruyn and others 1997). This study investigated patient opinion on oral rehabilitation by means of Brånemark implants. All patients were referred to a periodontal clinic for implant placement and treated by one clinician. Prosthetic restorations were performed by dentists with no previous experience with implant prostheses but who had completed a postgraduate training course. Patient opinions were obtained through questionnaires pertaining to satisfaction and oral function. Comparisons were made that compared the preoperative conditions with short-term (<4 months) and long-term conditions (3 years) after completion of the implant restorative treatment. In total, 61 patients participated in the study: 23 received mandibular fixed prostheses; 18 received maxillary fixed prostheses; 20 patients received fixed partial dentures (FPDs). The results indicated that a great majority of patients were very satisfied with the treatments. Comfort with eating, aesthetics, phonetics, and overall satisfaction improved significantly, and nearly all patients said that they would undergo the treatment again or recommend it to others. Patients reported that their implants felt as if they were “natural” teeth. Yi and others (2001) reported similar findings for treating periodontally compromised patients with fixed implant-retained prostheses. They found that, subjectively, patients reported improved and satisfactory oral function.

Custom cast abutments have been available for almost 20 years (Byrne and others 1998). There have been numerous reports regarding the adaptation of abutments to implants. This study assessed the adaptation of premachined, cast, and laboratory modified premachined abutments to implants at two sites: the abutment/implant interface and screw-to-screw seating. Byrne and others (1998) studied six different combinations of abutments and implants: CeraOne® abutments joined to Nobel Biocare AB (Göteborg, Sweden) implants; STR (3i, Implant Innovations, Inc., Palm Beach Gardens, FL) abutments joined to 3i implants; cast UCLA (3i) abutments subjected to porcelain firing cycles and joined to 3i implants; cast UCLA (3i) abutments subjected to porcelain firing cycles and joined to Nobel Biocare implants; UCLA premachined abutments cast with gold palladium alloy and subjected to porcelain firing cycles (later joined to 3i implants); and UCLA plastic abutments joined to 3i implants (Figure 8.5). Each group contained five separate assemblies. The authors found



Figure 8.1. Preoperative radiograph of a right maxillary posterior quadrant that demonstrated lack of adequate bone volume for implant placement due to pneumatization of the right maxillary sinus.

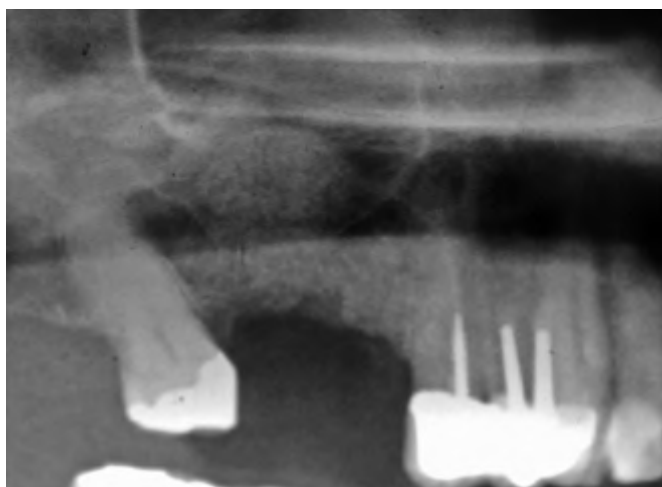


Figure 8.2. Radiograph of the same patient after bone was grafted into the floor of the sinus. This effectively increased the quantity of bone, which made it possible to place two implants into this quadrant.

that the adaptation of abutments to implants was closer and the amounts of contact larger for assemblies with premachined and laboratory modified premachined abutments than for those with cast abutments. They concluded that the finishing of custom-made abutments requires further refinement.

Vigolo and others (2000) reported that laboratory processing of implant-supported prostheses may alter the surface of the abutment in contact with the implant restorative platform, and thus negatively impact the fit between cast abutments and implant restorative platforms. They studied this in a laboratory setting and assessed potential changes at the implant restorative platforms of gold-machined

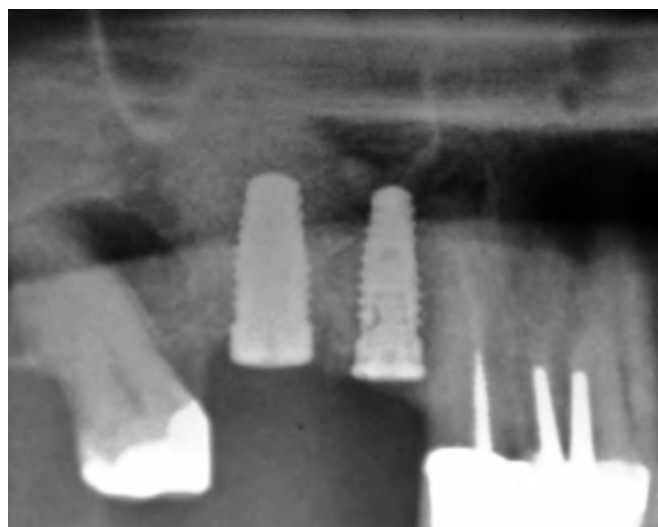


Figure 8.3. Radiograph of the same patient after implants were placed. The posterior implant was 5 mm in diameter; the anterior implant was 4 mm in diameter. The posterior implant replaced the first molar; the anterior implant replaced the second premolar.



Figure 8.4. Laboratory image of two posterior screw-retained implant crowns in the left posterior mandibular quadrant. The vertical height available for the implant restorations was approximately 13 mm. The patient also was a bruxer and had experienced difficulty retaining the previous cement-retained crowns. It was thought that retrievability of the restorations would be critical for long-term success. Screw-retained, splinted implant crowns provided an increased likelihood of success and predictable retrievability in case of porcelain fracture and/or screw loosening.

UCLA abutments after casting and porcelain applications in the case of single-tooth restorations. They studied the depth (d) and width (w) of the hexagonal portion of UCLA abutments, along with the apical diameters (D). The abutments' rotational freedom (R) were assessed for 30



Figure 8.5. Laboratory image of UCLA abutments (nonhexed [GUCA2C], left; hexed [SGUCA1C], right) for external hex implants, as received from Biomet 3i.

gold-machined UCLA abutments before casting procedures (time 0), after casting with a noble metal alloy (time 1), and after the addition of porcelain (time 2) to detect any changes in the abutments onto the external hex of the implants. They reported that no significant differences relative to any of the study parameters (d, w, D, and R) were observed between times 0, 1, and 2 ($P = 0.576$). Vigolo and others (2000) concluded that the results of their investigation suggested that if all laboratory steps were observed carefully, changes at implant interfaces of gold-machined UCLA abutments and implants would not occur.

However, there have also been reports of alterations in the fit between custom, cast abutments, and implant restorative platforms. Kano and others (2007) noted that misfit between implants and implant restorative components has been linked to restorative complications such as screw loosening. Although previous studies have shown a correlation between rotational misfit and screw loosening, Kano and others (2007) noted that the impact of casting procedures on rotational misfit was lacking. They reported the results of an in vitro study that evaluated the effect of casting procedures on rotational misfit of cast abutments when compared with machined titanium abutments. Forty-eight external hexagonal implants and 48 abutments were placed into four groups of 12 samples each: (1) machined titanium abutments; (2) premachined palladium abutments cast-on with palladium; (3) plastic burnout abutments cast with nickel chromium; and (4) plastic burnout abutments cast with cobalt chromium. Rotational misfit between the external hexagon of the implant and the internal hexagon of the abutment was measured using standardized techniques and recorded in degrees. Mean values for each group were analyzed with analysis of variance and Tukey test. The results of this in vitro study included a mean rotational misfit of 1.21 ± 0.57 degrees for machined titanium abutments, 1.77 ± 1.30 degrees for cast-on



Figure 8.6. Laboratory image of a UCLA abutment in place on an analog in a master cast, as received from the manufacturer.



Figure 8.7. Laboratory image of a custom, cast UCLA abutment fabricated for use as an abutment for a cement-retained crown. After the wax pattern was cast, it was abraded with $50\mu\text{m}$ aluminum oxide.

abutments, 1.98 ± 0.72 degrees for cast NiCr abutments, and 2.79 ± 1.13 degrees for cast CoCr abutments. Significantly greater rotational misfits were recorded with cast CoCr abutments when compared with machined titanium abutments ($P < 0.05$). Kano and others concluded that the rotational misfits found in this study were less than 2 degrees for all groups except for the cast CoCr abutments, which demonstrated a significantly greater rotational misfit. A typical use of a custom, cast UCLA abutment is illustrated in Figures 8.6–8.8.

With the introduction of computer-aided design/computer-aided manufacturing (CAD/CAM) technology for the fabrication of custom abutments, clinicians are able to provide patients with highly predictable, well-fitting, aesthetic restorations. CAD/CAM manufacturing has proven to be as accurate as casting custom abutments but without the



Figure 8.8. Laboratory image of the porcelain-fused-to-metal crown in place on the custom UCLA abutment featured in Figures 8.6 and 8.7.

potential for casting porosity and miscasts. Vigolo and others (2008) assessed the precision of fit at the implant restorative platforms of implants with gold-machined UCLA-type abutments and CAD/CAM titanium abutments with both external-hexagonal and internal-hexagonal connections. They made 15 gold-machined UCLA-type abutments with external-hexagonal connections, 15 gold-machined UCLA-type abutments with internal-hexagonal connections, 15 CAD/CAM titanium abutments with external-hexagonal connections, and 15 CAD/CAM titanium abutments with internal-hexagonal connections. The rotational freedom of the abutments was assessed to detect the precision of fit of each abutment on the implant restorative platforms. Measurements of the rotational freedom were compared among the four groups, and the quantitative differences among groups were assessed using one-way analysis of variance ($\alpha = 0.05$). They reported that significant differences relative to rotational freedom were not found among the four groups ($P > 0.19$) and concluded that both types of abutments (gold-machined UCLA-type and CAD/CAM titanium) consistently showed 1 degree of rotational freedom between the implants and the abutments in both external-hexagonal and internal-hexagonal connections. However, this study did not report on the problems associated with casting custom abutments in terms of porosity.

THE ENCODE® COMPLETE RESTORATIVE SYSTEM

Since 2004, it has been possible to fabricate custom milled titanium abutments, Patient Specific Restorations®, using the Encode® Restorative System. (Biomet 3i, Palm Beach Gardens, FL) With this system, surgeons place special healing abutments (Encode Healing Abutments) that have been manufactured with computer codes embedded into



Figure 8.9. Occlusal view of Encode Healing Abutments (5-, 6-, and 7.5-mm emergence profiles, left to right). The occlusal codes can be read by a scanner/computer and can identify the orientation and type of the hex connection, the size of the implant restorative platform, and the implant/abutment interface. IEHA554, IEHA564, and IEHA574 (left to right).



Figure 8.10. Profile view of an abutment screw going into an Encode Healing Abutment (IEHA454). This healing abutment was designed with a 4.1-mm implant restorative platform (internal connection, blue). In order for this system to function, the healing abutment must be correctly seated onto the hex of the implant restorative platform.

their occlusal surfaces (Figure 8.9). These healing abutments may be placed at the time of implant placement or at the time the implants were uncovered with a two-stage surgical protocol. Encode Healing Abutments have been designed as two-piece healing abutments (Figure 8.10) and are available in multiple collar heights (3, 4, 6, and 8mm) (Figure 8.11). They are available for 3.4-, 4.1-, 5-, and 6-mm implant restorative platforms.

The Encode® Complete Restorative System (Biomet 3i) eliminates the need for implant-level impressions while delivering custom milled titanium abutments that have appropriate gingival margin heights relative to the peri-implant soft tissues and natural emergence contours for a given implant restoration. Definitive abutments are designed and milled from an impression of an Encode

Healing Abutment in place intraorally (Figure 8.12). Codes embedded onto the occlusal surface of the Encode Healing Abutment identify the collar height, implant hex orientation, platform diameter, and implant interface (the Certain® Internal Connection or External Hex Connection, Biomet 3i) to the computer and abutment designer.

Once the surgeon places Encode Healing Abutments at the time of implant placement or at implant uncovering, and the soft tissues mature, the Encode Complete Restorative System eliminates the need for implant-level impressions. The restorative dentist does not need to disturb soft tissue healing by removing and replacing the healing abutments or by using traditional implant impression copings. The restorative dentist needs only to make a crown and bridge type of impression of the Encode

Healing Abutment(s). The occlusal surfaces of the healing abutments have to be at least 1 mm supragingival around the entire circumference so as to completely expose the codes on the occlusal surfaces of the Encode Healing Abutments (Figure 8.13). The definitive impression of the Encode Healing Abutment, the opposing cast, the interocclusal record (if needed), and the shade for the definitive crown are sent to a commercial dental laboratory for processing. Die stone is mixed per the manufacturer's instructions, and a master cast is poured in conventional fashion (Figure 8.14). It is essential that the master cast is not pinned, in anticipation of robotic analog placement (Figure 8.15).

For Encode Abutments, the casts must be mounted in a system-compatible articulator with Adesso magnetic



Figure 8.11. Profile view of Encode Healing Abutments (5-, 6-, and 7.5-mm emergence profiles, left to right). These healing abutments were designed with 5-mm implant restorative platforms. All had 4-mm collar heights. IEHA554, IEHA564, and IEHA574 (left to right).



Figure 8.13. Clinical occlusal view of an Encode Healing Abutment in place in a maxillary left lateral incisor space. The entire occlusal surface of the healing abutment is supragingival, and all of the computer codes are visible.

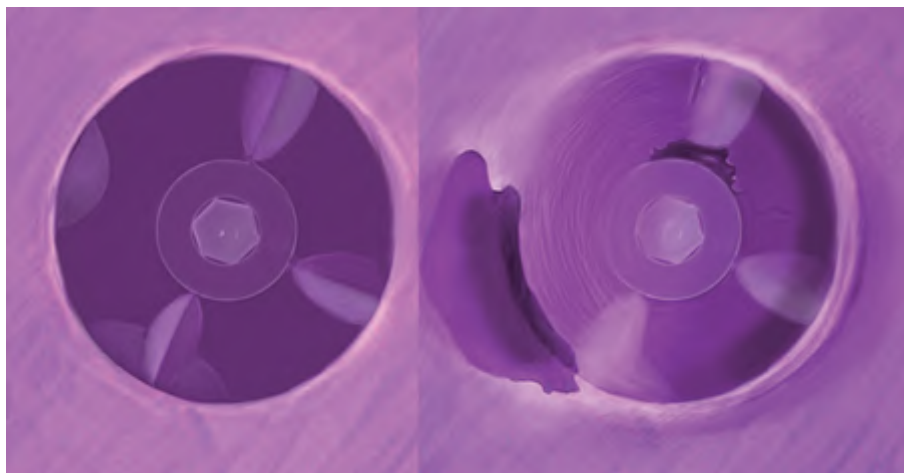


Figure 8.12. Illustrations of a satisfactory impression of an Encode Healing Abutment (left); unsatisfactory impression of an Encode Healing Abutment (right).



Figure 8.14. Laboratory occlusal view of the master cast with the die of the Encode Healing Abutment. The scanner will be able to process the digital information of the codes in order to identify the type of the implant/abutment connection, the orientation of the implant hex, the collar height, and the size of the implant restorative platform. The soft tissue margins will also be recorded in anticipation of the design of the definitive abutment.



Figure 8.15. Laboratory image of the underside of a cast, received at the PSR Department, Biomet 3i, that was pinned as in conventional fixed prosthodontics. The pins made this cast unacceptable for use with the Encode Complete Restorative System robotic lab analog placement.

mounting plates (Stratos™ 100, Ivoclar Vivadent, Amherst, NY) (Figure 8.16). The casts also must be mounted directly in line with the mounting plates; the occlusal table must be centered vertically between the upper and lower members and the incisal guide pin must be set at zero (Figure 8.17). A common articulator mounting error that has been reported occurs when, prior to mounting the casts, the incisal guide pin has not been zeroed at the commercial dental laboratory. Incorrectly mounted casts will have a major impact on the virtual articulator mounting in the computer (Figures 8.18 and 8.19). Laboratory tech-



Figure 8.16. Laboratory image of casts correctly mounted in a system-compatible articulator. Note that the casts were mounted directly in line (vertically and horizontally) with the mounting plates and that the occlusal plane was centered vertically and horizontally within the articulator.



Figure 8.17. Illustration of casts that were incorrectly mounted relative to the Encode Complete Restorative System protocol: the occlusal plane was not centered vertically between the upper and lower members, and the casts were mounted significantly anterior to the mounting plates.



Figure 8.18. These casts were placed onto the verification articulator at the PSR Department. This articulator is calibrated every day. This articulator mounting was not accurate as the premolars did not have occlusal contacts. The case was returned to the commercial dental laboratory for remounting.



Figure 8.19. This is an image of an incisal guide pin (on the calibrated articulator in the PSR Department) that did not contact the incisal guide table by at least 4 mm. Note the pad of paper that was placed between the incisal guide pin and the incisal guide table to indicate the amount of error. This mounting was not accurate and the casts were returned to the commercial dental laboratory for remounting.

nicians at commercial dental laboratories complete the work orders (Figure 8.20) and send the mounted casts to Biomet 3i's Architech PSR® Department.

The cast with the Encode Healing Abutment (in stone) is then scanned at the PSR Department. The scanner interprets the codes and the dental and gingival architecture. The digital data are sent to PSR designers for design of the definitive Encode Abutment, as well as to the laboratory for fabrication of the Robocast (Biomet 3i). Robocast technology involves placement of the appropriate implant lab analogs into a cast by virtue of the digital data obtained from the scan of the Encode Healing Abutment cast. The original Encode Healing Abutment cast is then robotically modified to accept the appropriate laboratory analog. The robot will take the digital data and remove the stone in the indicated area. The implant lab analog is positioned, oriented, and secured into the cast that replicates the implant position in the patient. This results in fabrication of a Robocast, which the commercial dental laboratory uses to fabricate the definitive restoration (Figures 8.21–8.27).

At the same time that the Robocast was being made, the Encode Abutment was designed (Figure 8.28). A CAD healing abutment master drawing is aligned over the healing abutment scan data for abutment design and placement accuracy. Implant depth, interface, hex orientation, and platform diameter are captured relative to the interproximal and opposing dentitions, emergence profile requirements, and gingival margins. In proprietary CAD software, the PSR technicians design the patient-specific definitive abutment with appropriate margin height and natural emergence contours according to the laboratory technician's and clinician's specifications. The virtual abutment design data are sent to the CAM Center and milled from a titanium alloy blank. All of the blanks have pre-machined interfaces for optimal implant/abutment fit and are used for definitive Encode Abutments. After it has been milled, the Encode Abutment is placed onto the master cast, and the case is returned to the commercial dental laboratory for fabrication of the crown restoration (Figure 8.29).

CLINICAL PATIENT PRESENTATION

The patient presented to the prosthodontist (Dr. Watkins) with a chief complaint, "The bridge on the lower right is loose. If it has to come out, I don't want to wear a partial." The FPD was approximately 15 years old and had been loose for about 2 months. The patient had no dental concerns and was in good general health.

The radiographic examination revealed a dentition in good repair and dental pathology in the mandibular right



Figure 8.21. This is the robot that removes the stone from the master cast in the implant site and places the laboratory analog in its correct 3-D position.



Figure 8.22. Laboratory occlusal image of an Encode Healing Abutment in stone. Note that the codes were clearly visible and the occlusal surface of the healing abutment was at least 1 mm supragingival around the entire circumference of the abutment.



Figure 8.24. Laboratory occlusal image of the hole drilled by the robot.



Figure 8.23. Laboratory image of the robot with a drill bit in place, removing stone in the area of the Encode Healing Abutment.



Figure 8.25. Laboratory image of a 4-mm implant laboratory analog attached to the holder in the robotic arm.



Figure 8.26. Laboratory image of the 4-mm implant laboratory analog held in its correct 3-D position by the robotic arm. The analog was secured into place with cyanoacrylate cement. The remnants of the cyanoacrylate activator can be seen on the stone cast.



Figure 8.27. Laboratory occlusal image of the implant lab analog in its correct 3-D position in the master cast. Note the lack of any type of emergence profile or soft tissue replica in the cast. The emergence profile of the definitive Encode Abutment will be designed consistent with the digital information obtained from the codes of the scanned Encode Healing Abutment.



Figure 8.28. Five Encode Abutments. Note that the emergence profiles of the abutments are independent of the peri-implant soft tissue contours because they were established from the peri-implant contours of the scanned casts.



Figure 8.29. Laboratory occlusal image of the five Encode Abutments milled from the designs from Figure 8.28. Optimal, anatomical emergence profiles have been milled into the abutments. The ceramist will make the crown restorations fit into the emergence profiles and gingival margins of the machined abutments.



Figure 8.30. Complete, preoperative periapical radiographic series that demonstrated an intact dentition, dental caries, moderate bone loss secondary to periodontal disease, and previous endodontic therapy.

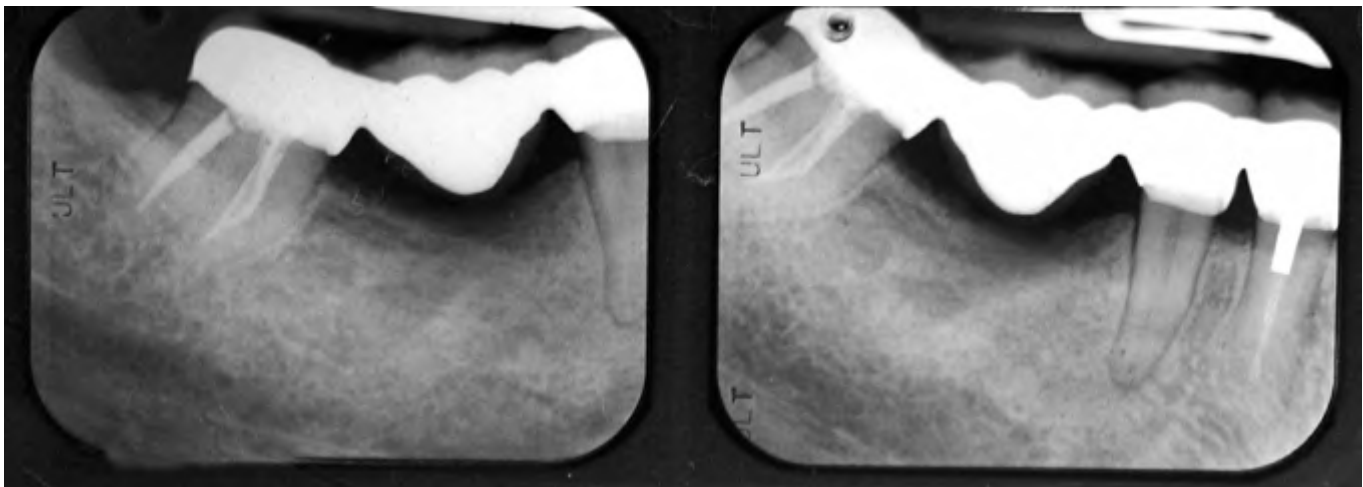


Figure 8.31. Two periapical radiographs of the teeth and preexisting FPD in the mandibular right posterior quadrant. The distal caries, widened periodontal ligament space, and previous endodontic treatment with a post in the canal space are evident in the mandibular second molar, second premolar, and first premolar, respectively.

posterior quadrant, including past endodontic treatment and distal caries beneath the distal retainer, a widened periodontal ligament space around the second premolar, and past endodontic treatment with a post in the first premolar (Figures 8.30 and 8.31).

The patient presented with no other medical or dental concerns.

DIAGNOSIS

The following diagnoses were established:

1. Recurrent dental caries, tooth #31
2. Probable root fracture, tooth #29

3. Recurrent dental caries, tooth #28, with possible root fracture
4. Partially edentulous maxillae and mandible
5. Previously placed, osseointegrated implant replacing the mandibular left first molar
6. Multiple endodontically treated teeth
7. Stable occlusion

ASSESSMENT

The preexisting FPD was considered to be nonrestorable. If the abutment teeth proved to be compromised, the patient could have them extracted or undergo periodontal

surgery to improve the local dental anatomy for optimal crown preparations and gingival contours. The preexisting endodontic therapy would likely have to be redone. All of the teeth had a compromised prognosis. If the teeth were to be extracted, immediate grafting procedures would be accomplished at the time of extraction in order to prepare the sites for future implant placement.

The patient was scheduled for the above procedures, and the FPD was removed. Teeth #29 and 31 were found to have extensive caries (#31), or were fractured (#29). The mandibular first premolar was initially considered salvageable but was also eventually extracted, secondary to a root fracture. With the loss of all of the posterior teeth in the right mandibular quadrant, the patient decided on having four implants placed with four individual crown restorations. The patient was referred to the oral surgeon (Dr. Kuzmik) for extraction and grafting. These procedures were accomplished uneventfully, and the patient returned to the prosthodontist for the diagnostic workup in preparation for implant placement and restoration.

DIAGNOSTIC CASTS/SURGICAL GUIDE

Orders were written for duplication of the original diagnostic casts and articulator mounting. A processed acrylic resin surgical guide was fabricated on the cast (Figures 8.32 and 8.33). Surgical guide tubes (SGT25, Biomet 3i) (Figure 8.34) were processed into the surgical guide to assist the surgeon in optimal implant placement, consistent with the location of the implant restorations (Figure 8.35). The stainless steel tubes were designed to be used as guides for surgeons during preparation of an osteot-

omy. They were not designed for precise implant placement available with computed tomography (CT)-guided surgical protocols.

IMPLANT SURGERY

The surgeon placed four implants into the mandibular right posterior quadrant, using a two-stage surgical protocol,



Figure 8.33. Laboratory image of the processed acrylic resin surgical guide with guide tubes in place, on the mandibular diagnostic cast.

☐ Gold Post	☐ Inlay/Onlay	☐ Tap & Screw	☐ Full gear, Act.
☐ Telescopic Coping	☐ Cast/Max Core	☐ Cast/Max Core	☐ Bursal cap only
☐ Concept Inlay/Onlay			
☐ Bridge			
☐ Apple Punt			
☐ Resque Base			

Additional Instructions:

- Please Draw P.I. Dr. Cast & Mount (1) Set on A
- Please Indicate Surgical Stents:
- #13 → Make stent to extend to #9 for support
- #29, 30 & 31 → Make stent to extend to #22 for support

Tooth form to follow in final restorations.

LAB USE/INITIAL AS DONE ARTICULATION: <i>DRY</i> DEC: <i>1-07</i> WAX: <i>1-07</i> FORM FIT: <i>1-07</i> DR'S NAME:	CERAMIC COLOR: SHIM OCCLUSION: ARCH FORM: INSTRUCTIONS COMPLETED: LICENSE NUMBER:	DR'S INITIALS: <i>BD</i> ASSISTANT'S INITIALS: <i>SD</i>
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Figure 8.32. Diagnostic casts were made. This is the work order for a custom, processed acrylic resin surgical guide to be fabricated directly on the mandibular cast. Surgical guide tubes were to be placed, at the surgeon's direction, into the guide to assist in optimal location of the implants per the treatment plan.



Figure 8.34. Stainless steel stent guide tubes, as received from the manufacturer, have been machined with 2.4-mm inner diameters (SGT25). These have been designed to be used with 2-mm twist drills during preparation of implant osteotomies.



Figure 8.35. The surgical guide was processed in acrylic resin; the surgical guide tubes were cured into the surgical guide in positions that were dictated by the implant surgeon during the treatment planning phase.



Figure 8.36. This panoramic radiograph was taken immediately post insertion of the four implants in the right posterior mandibular quadrant. The implants were placed with a two-stage protocol; cover screws were placed at the time of surgery, and the implants were “buried.”

with unloaded healing. The patient did not wear a removable partial denture during this period. The surgeon selected implants with platform switching (Lazzara and Porter 2006) built into the design of the implant restorative platforms (NanoTite™ Certain Prevail® Implants, Biomet 3i) (Figure 8.36). The surgeon recommended a 6-month healing period prior to uncovering the implants.

Platform switching involves placing implants with certain-sized implant restorative platform diameters and restoring the implants with restorative components that are narrower than the implant restorative platforms (Figure 8.37). Long-term radiographic follow-up of “platform-switched” wide-diameter dental implants, with narrower restorative



Figure 8.37. Illustration of platform switching. The implant restorative component is narrower than the restorative platform of the implant. Since the microgap between the implant abutment and the implant was moved medially, there will be less inflammation in the bone adjacent to the implant, and should result in less bone loss than seen with implants restored with restorative components that match the implant restorative platforms.

components, has demonstrated a smaller than expected vertical change in the crestal bone height around these implants than is typically observed around implants restored conventionally with prosthetic components that match implant diameters. Lazzara and Porter’s (2006) radiographic observations suggested that the resulting postrestorative biological process resulting in the loss of crestal bone height was altered when the outer edge of the implant/abutment interface was horizontally repositioned medially and away from the outer edge of the implant restorative platforms. This publication introduced the concept of platform switching and provided a foundation for future advances in the biology of the observed radiographic findings and clinical rationale for this technique. Platform switching is available from multiple implant manufacturers. Figure 8.38 illustrates several examples of implants with platform switching built into the implant designs from Biomet 3i.

PLACEMENT OF HEALING ABUTMENTS

The patient healed uneventfully, and the 6 months passed without incident. At this time, the definitive abutments had not been selected. Therefore, at the second surgical appointment, the surgeon placed conventional healing abutments (Figures 8.39 and 8.40).



Figure 8.38. Illustrations of NanoTite Certain Prevail Implants with the following dimensions (left to right): NILOS4311—4-mm-diameter implant body, 4.1-mm-diameter implant restorative platform, 3.4-mm restorative seating surface; NILOS4511—4-mm-diameter implant body, 4.8-mm-diameter implant restorative platform, 4.1-mm-diameter restorative seating surface; NILOS5411—5-mm-diameter implant body, 5-mm-diameter implant restorative platform, 4.1-mm-diameter restorative seating surface.



Figure 8.39. Occlusal view of EP® Healing Abutments as received from the manufacturer (Biomet 3i). The large number on the left side of each healing abutment corresponds to the height of the healing abutment; the numerator of the fraction on the right side of the healing abutments corresponds to the diameter; the denominator of the fraction corresponds to the diameter of the implant restorative platform. Healing abutments are selected consistent with the size of the teeth being replaced.



Figure 8.40. EP Healing Abutments are available from Biomet 3i in the following heights: 2, 3, 4, 6, and 8 mm (left to right).

The healing abutments were selected consistent with the top-down treatment planning approach (Lazzara 1994). With the availability of osseointegrated implants in an assortment of diameters as well as lengths, the implant selection process has become more complex. To expand treatment options and optimize outcomes, implant selection should be guided by a number of surgical considerations and prosthetic requirements specific to each implant site. Small-diameter implants are appropriate in areas of narrow ridge dimensions or where prosthetic space is limited. Wide-diameter implants are well suited to posterior regions with poorer bone quality and restricted vertical height. Wide-diameter implants provide a higher degree of implant-to-bone contact, increased initial stability, reduced screw stress, and anatomical emergence profiles consistent with the teeth being replaced.

The healing abutments for the premolars had emergence profile diameters of 5 mm; the healing abutment for the first molar had a 6-mm emergence profile; the healing abutment for the second molar had an emergence profile of 7.5 mm (Figures 8.41 and 8.42).

PLACEMENT OF ENCODE HEALING ABUTMENTS AND ENCODE HEALING ABUTMENT IMPRESSION

The prosthodontist decided that custom CAD/CAM abutments would be the treatment of choice for the mandibular right posterior implant restorations. He also decided that the implants and implant restorations did not need to be splinted; he did not want screw access openings in the occlusal surfaces of the restorations. Therefore, he



Figure 8.41. Lateral clinical image of the patient in centric occlusion, 3 weeks after the implants were uncovered, with the conventional healing abutments in place. All of the healing abutments were selected based on the size of the missing teeth in each implant site. All of the healing abutments were out of occlusion.



Figure 8.42. Occlusal clinical image of the patient 3 weeks after the implants were uncovered. The numbers on the occlusal aspects of the healing abutments identify the heights, emergence profile diameters, and implant restorative platforms.

treatment planned four individual custom abutments and four individual cement-retained crowns.

Jemt (2008) reported on long-term data that compared cemented and screw-retained single-implant crown restorations. He compared the clinical and radiographic performances of single-implant crown restorations made by either directly baked porcelain to custom-made TiAdapt® titanium abutments (Nobel Biocare AB) (test) or cemented crowns onto CeraOne (Nobel Biocare AB) abutments (control) after 10 years in function. Thirty-five consecutive patients were provided with 41 turned single Brånemark System® implants (Nobel Biocare AB) in partially edentulous maxillae. Randomly, 15 and 20 patients were provided with 18 test and 23 control implant crowns, respectively. Thereafter, clinical and radiographic data were collected and compared between the two groups. Jemt (2008) reported that none of the implants failed during the 10-year follow-up period (cumulative survival rate [CSR] = 100%). Few clinical problems were observed, and the overall average marginal bone loss was 0.26 mm (SD = 0.64) during the 10 years that patients were followed in this study. After final tightening of the abutment screws, no significant differences were observed between the test and control groups ($P > 0.05$). Jemt (2008) concluded that there seemed to be no obvious clinical or radiographic differences between the test and control single-implant restorations during the 10 years of follow-up in this study. Occasionally, some restorations presented loose abutment screws and/or fistulas during follow-up. This implied a certain need for maintenance where a one-piece single-implant protocol (test) allowed both for a simple clinical procedure at placement without cementation problems, as well as for an easy and simple maintenance of



Figure 8.43. This is a clinical occlusal image of the mandibular right posterior quadrant with the Encode Healing Abutments in place. All of the codes on the occlusal surfaces of the healing abutments are completely visible around the entire circumferences of each healing abutment.



Figure 8.44. This is a clinical buccal image of the patient's mandibular right posterior quadrants, with the patient in centric occlusion. Note that the Encode Healing Abutments were taller than the original conventional healing abutments but still did not interfere with centric occlusion.

installed single-implant crowns in long-term function. Other researchers have reported few clinical problems with single-implant crown restorations (Scheller and others 1998; Gotfredsen 2004).

Specialized healing abutments (Encode Complete Restorative System) were selected consistent with the implant restorative platforms, emergence profiles, and collar heights (Figure 8.43). The prosthodontist used taller Encode Healing Abutments, as compared with the original healing abutments, for accurate scanning in order to visualize all of the codes on the occlusal surfaces of the Encode Healing Abutments (Figure 8.44). The heights of the domed occlusal portions of the healing abutments must extend at least 1 mm above the gingival margins



Figure 8.45. This is a radiograph that demonstrated complete seating of the Encode Healing Abutments onto the restorative platforms of the implants. The healing abutments maintained the concept of platform switching that began with the implant design selected prior to implant surgery.

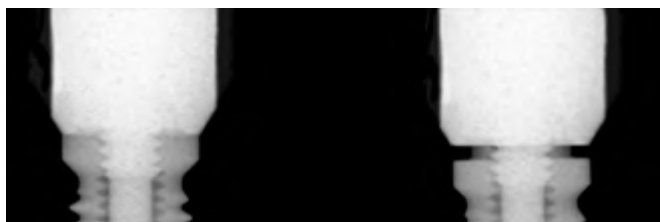


Figure 8.46. This radiograph demonstrates the differences between complete seating of a healing abutment (left) and incomplete seating of a healing abutment (right) onto implant restorative platforms.

around each of the healing abutments because parts of the codes extended slightly onto the axial walls of the Encode Healing Abutments.

Encode Healing Abutments consist of two pieces: the abutment screw with a large hex (0.048in) and the abutment body. The bodies of the healing abutments were designed with a hex interface that engages the hex connection of the implants. Proper seating of healing abutments must be verified with radiographs (Figures 8.45 and 8.46). The abutment screws were tightened to 20Ncm with a torque indicator prior to making the definitive impression.

The definitive impression was made with polyvinyl siloxane impression material (Figure 8.47). After the impression



Figure 8.47. A full-arch impression was made of the Encode Healing Abutments with polyvinyl siloxane impression material. The impression captured all of the requisite data on the occlusal surfaces of the Encode Healing Abutments.



Figure 8.48. Careful inspection of the impression revealed excellent detail and accurate impressions of the Encode Healing Abutments.

material set, the impression tray was removed from the mouth and the impression was examined to verify that an accurate impression had been made of all the Encode Healing Abutment occlusal codes, including the entire circumferences of the healing abutments, as well as the soft tissue contours (Figure 8.48).

MASTER CAST

The impression was poured with low-expansion die stone per the manufacturer's instructions (Figure 8.49). The cast was large enough to allow for insertion of the appropriate implant analogs.



Figure 8.49. A full-arch cast was poured in die stone per the manufacturer's instructions. Pins were not used in this cast.



Figure 8.50. This is a close-up laboratory view of the occlusal surfaces of the Encode Healing Abutments in the mandibular right posterior quadrant. All of the occlusal codes were visible. The voids/defects in the areas of the abutment screw/abutment interface were not important since the important information for the CAD/CAM abutment was contained in the occlusal codes of each Encode Healing Abutment.

The cast was carefully inspected to verify that all of the occlusal codes had been satisfactorily replicated from the impression (Figure 8.50). For accurate scanning, Encode Healing Abutment casts must provide the following:

1. Complete visibility of the occlusal surfaces (defect free)
2. One-millimeter visibility of the axial walls
3. Accurate and defect-free duplication of the peri-implant soft tissues around each healing abutment



Figure 8.51. This is an example of casts correctly mounted within an articulator with Adesso mounting plates. The casts were centered vertically, consistent with the horizontal pin of the incisal guide pin. They were also centered directly in line with the mounting plates. The clinical heights of the Encode Healing Abutments replicated in die stone were sufficient for scanning.

For this particular protocol, dowel pins were not placed as in the implant-level impression protocol. Instead, the analogs would be placed by a robot. Therefore, the casts were solid, including the cast base. Plates also could not be used per the robotic analog placement technology.

ARTICULATOR MOUNTING

The casts were hand articulated and mounted on an articulator compatible with Adesso® Split Mounting Plates (Baumann Dental GmbH, Ellmendingen, Germany) such as the Ivoclar Stratos 100 (Figure 8.51). Prior to mounting the casts, the articulator was calibrated and zeroed as per the manufacturer. This articulator was adjusted with the patented centering key; the manufacturer has stated that the Adesso split-system has micrometer accuracy, between articulators, when adjusted properly (www.modelsystem-2000.com/english/pdf/prospekte/e_26660.pdf). The casts were centered within the articulator, with the incisal edges of the maxillary anterior teeth aligned with the horizontal pin on the incisal guide pin. Casts must be centered on the mounting plates since the scanners read the casts relative to where the plates are located. If a cast is not centered within the mounting plates, the cast and healing abutments cannot be correctly placed into the scanner and will not be correctly scanned (Figure 8.52). The incisal guide pin at both laboratories has to be set at zero (Figure 8.53).



Figure 8.52. In this case, the casts that were mounted on the articulator in a commercial dental laboratory did not transfer accurately to the laboratory at PSR, as the incisal guide pin did not touch the incisal guide table. The casts had to be returned to the original commercial dental laboratory for remounting.



Figure 8.53. This case was originally mounted in an articulator that was not calibrated properly. The casts were transferred to the articulator at the PSR Department; the incisal guide pin contacted the incisal guide table at the PSR Department. However, the casts were not in occlusion. The casts were returned to the commercial dental laboratory for remounting in a verified, zeroed articulator.

ENCODE COMPLETE WORK ORDER

The work order was completed and signed by the dental laboratory technician (Figure 8.54). In this case, the dental laboratory technician specified the following:

1. The implant sites by tooth number
2. Identified the implant abutment connection as Certain
3. Specified that none of the Final Encode Abutments should receive gold-colored titanium nitride coatings
4. All of the implant sites should have the implant analogs placed by the robot
5. Chamfer margins
6. Facial and interproximal margins to be placed 1 mm subgingival
7. Lingual margins to be placed at the gingival crest
8. The interocclusal distances between the occlusal surfaces of the abutments and the occlusal surfaces of the opposing teeth to be 2mm
9. The contour guidelines were to be standard
10. All of the abutments were to be polished
11. Robotic placement of the analogs, consistent with the Encode Healing Abutments in the cast

The casts and mountings were carefully wrapped in bubble paper and sent to the Patient Specific Products (PSP) Department, Biomet 3i, 4555 Riverside Drive, Palm Beach Gardens, FL.

SCANNING

The casts were received at the PSR Department, Biomet 3i, and placed onto the articulator, which is verified on a daily basis. The original articulator mounting was verified as accurate.

The casts were placed into a laser scanner (D-250™ 3D Scanner, 3Shape A/S, Copenhagen, Denmark) (Figures 8.55 and 8.56). This particular company offers 3-D scanning systems that create accurate 3-D models from real objects at the push of a button. The Web site stated that all of the scanners use optical technology to capture casts' geometries precisely and are said to offer an intuitive user-friendly interface (www.3shape.com).

According to the above Web site, 3Shape's dental solutions are a unique combination of 3Shape's expertise in 3-D scanning and 3-D CAD software that provide clinicians and dental laboratory technicians integrated solutions for

Work Order

* 1. Account Information

* Laboratory Name:

BIOMET **3i** Account#:

* Contact: _____

* Phone: _____

Fax: _____

* Email: _____

* Patient ID:

* Ship To:

Bill To: _____

* 2. Preparing Your Case For Shipment

- Use only die stone for Encode Complete Casts
- Verify that all of the codes on each healing abutment are completely visible on the cast
- Mount casts on Adesso Split Plates Articulator **only** (Stratos® or Baumann) and verify the vertical pin is set at zero and meets the occlusal table
- Following mounting on the designated articulator, please include the following in the shipment to BIOMET 3i:
 - ☐ Encode Cast
 - ☐ Opposing cast
 - ☐ Copy of the completed work order
- All unarticulated or misarticulated casts will be returned to the laboratory
- Please **do not** send the articulator
- Analogs cannot be placed in sectioned or pinned casts
- **Please make sure there is no metal in the cast.** The laboratory is responsible for any damage to BIOMET 3i Equipment or personnel caused by metal in the cast

* 3. Case Information

[illegible]

**** NOTE:** TiN Coating will add two working days to the processing of your abutment. If a box is not checked the abutment will not be TiN coated.

* 4. Design Guidelines

Margin Style – Select One

- ☐ Shoulder
- ☐ Chamfer (default)

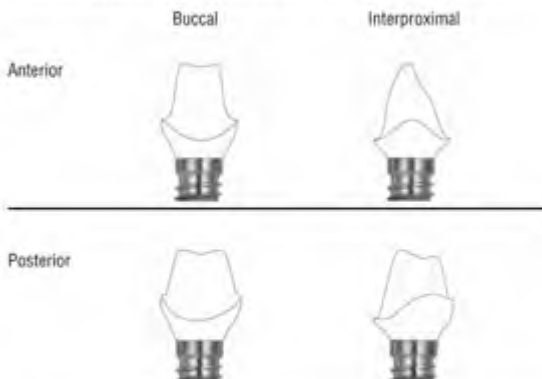
Interocclusal Distance: _____ mm

NOTE: Default on all margins = 1mm Subgnival

* REQUIRED FIELD

5. Contour Guidelines

Please draw the approximate contour desired over the default images below.
Note margin style. Please draw in tissue contour.
(Minimum abutment height = 4mm and minimum collar height = .5mm)



6. Special Instructions

- ☐ Polish entire abutment (default) ☐ Only polish the subgingival collar

☐ See back or attached page for additional instructions.

7. Screw Ordering

- ☐ I would not like to order screws at this time.

<u>Certain Abutment Screws</u>	<u>Qty.</u>
Gold-Tite® Hexed (IUNIHG)	
Titanium Hexed (IUNIT)	
Laboratory Hexed Try-in Screw - 5 pack (IUNIT)	
<u>External Hex Abutment Screws</u>	<u>Qty.</u>
Gold-Tite Square (UNISG)	
Gold-Tite Hexed (UNIHG)	
Titanium Hexed (UNIT)	
Laboratory Square Try-in Screw - 5 pack (UNIT)	
Microminiplant™ Square Try-in Screw - 5 pack (MUNIT)	

* 8. Certification — must be signed

I certify that the stated information is correct and that the submitted materials are accurate and contain no metal. All items that have contacted the oral environment have been disinfected. This form authorizes BIOMET 3i to fabricate the patient specific abutment(s) and place analogs using and consistent with the information provided on this work order.

Technician Signature _____

Date _____

Internal Use Only

Job #: _____

Signature: _____

BIOMET 3i

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REV F 02/08

Figure 8.54. Work order for Encode Abutments.



Figure 8.55. D-250 3D Scanner. The opaque black glass doors were open for this photograph and exposed the magnetic mounting plate that accepts the Adesso Mounting Plates.



Figure 8.56. The interior section of the D-250 3D Scanner with a close-up view of the mounting plate that accepts the Adesso Mounting Plates.

the creation of accurate customized, CAD/CAM dental restorations.

3Shape's dental restoration system is completely open (output files are in a standard format) and offers advanced 3-D technology. This system allows scans of full casts, dies, or wax patterns, and designs full anatomical crowns, FPD frameworks, or implant abutments from the scanned data. 3Shape's open system allows manufacturers the possibility to manufacture products in compatible milling units and materials, as well as the benefit from the increasing number of outsourcing production centers.

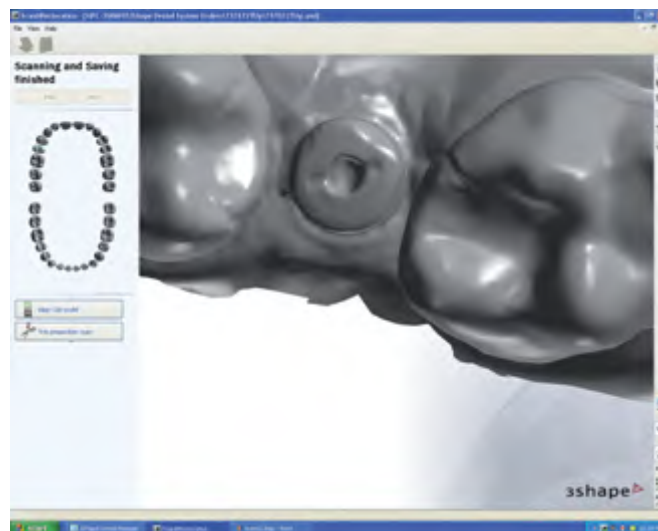


Figure 8.57. This is a low-resolution computer screen shot of the first scan in the sequence of designing an Encode Abutment.

3Shape's DentalManager™ software program allows for automatic handling of all production files and transfer of the files to manufacturing equipment and/or outsourcing centers.

ABUTMENT DESIGN/MILLING

The digitized data from the scanning of the Encode Healing Abutments (in die stone) were imported to the personal computer workstation of one of the PSP designers (Figure 8.57). A verification process was carried out to verify that the Encode Healing Abutments, as scanned, represented an accurate impression of the Encode Healing Abutments in the patient's mouth (Figure 8.58). The abutments were custom designed per the instructions on the work order relative to margin type and location, total occlusal convergence, and interocclusal clearances between the occlusal surfaces of the abutments and the opposing occlusal surfaces (Figures 8.59–8.61). The abutments were designed in CAD design software. In some cases, the CAD designs can be e-mailed to dental technicians for review, input, and discussion. This discussion has to be arranged prior to design.

The design data were sent to a milling machine (Mikron HSM 400, Mikron Agie Charmilles, Nidau, Switzerland) for milling the titanium alloy abutments per the CAD designs described above (Figure 8.62). The manufacturer has stated that with these machines, accuracy, extreme dynamics, and high machining speeds have been combined with other important manufacturing aspects such as outstanding swarf removal, high flexibility, good ergo-

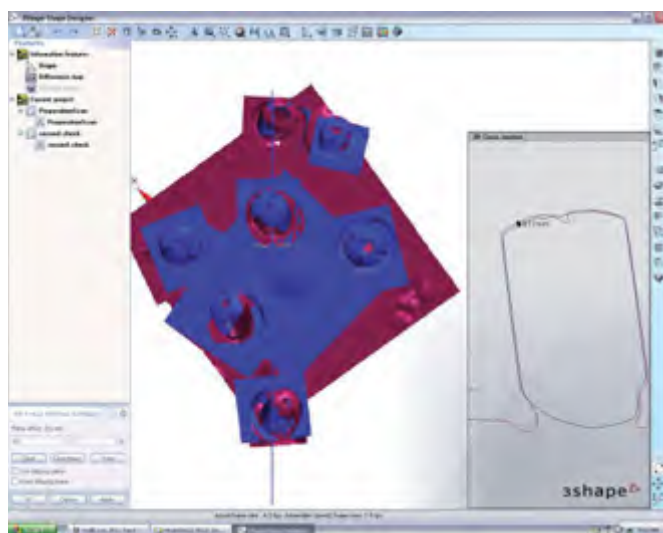


Figure 8.58. This is a computer screen image of the verification process used in the Encode Complete protocol. The blue portion of the image is the result of the scanned Encode Healing Abutment, in die stone, from a cast received at Biomet 3i. The red portion is the image from an actual Encode Healing Abutment that was placed on the analog in the Robocast. The cross-sectional image on the right side of the photograph indicates that the scanned image of the Encode Healing Abutment (die stone) was replicated by the scanned image of an actual Encode Healing Abutment placed on the analog of the Robocast.



Figure 8.59. CAD designs of the buccal surfaces for the abutments in the right mandibular posterior quadrant. The total occlusal convergence for each abutment was approximately 6 degrees. The facial margins were 1 mm subgingival.

nomics, and well-integrated automation. According to the manufacturer's Web site, the unique flexibility of the HSM 400U ProdMed Dental milling unit is a key success factor by both time-to-prototype and productivity assessments. Reverse engineering has enabled dental solution providers to quickly and accurately bridge the gap between the

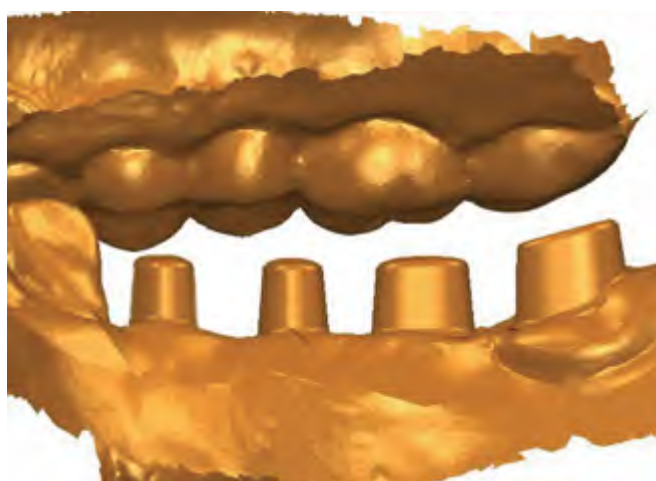


Figure 8.60. CAD designs of the lingual surfaces for the abutments in the right mandibular posterior quadrant. The lingual margins were designed to be approximately 1 mm supragingival.



Figure 8.61. CAD designs of the occlusal surfaces for the abutments in the right mandibular posterior quadrant. The margins of all the abutments are completely visible, indicating one path of insertion.

physical and digital worlds by reading any point cloud data set, whether it is generated by a touch trigger, laser, or optical hardware system (www.gfmc.com/gfac/products/high-speed-machining-centers/hsm-prodmed/mikron-hsm-400u-prodmed-dental.html?L=http%3A%2F%2Fwww.t-cross.com%2Fcgi%2Fannounce%2Fimages%2Fasawux%2Fuki%2F).

The abutments were milled and polished (Figure 8.63).

ROBOTIC PLACEMENT OF LAB ANALOGS INTO CAST (ROBOCAST)

The cast was placed into the cast holder, and the operator set the instrument for the robot to remove the stone in the

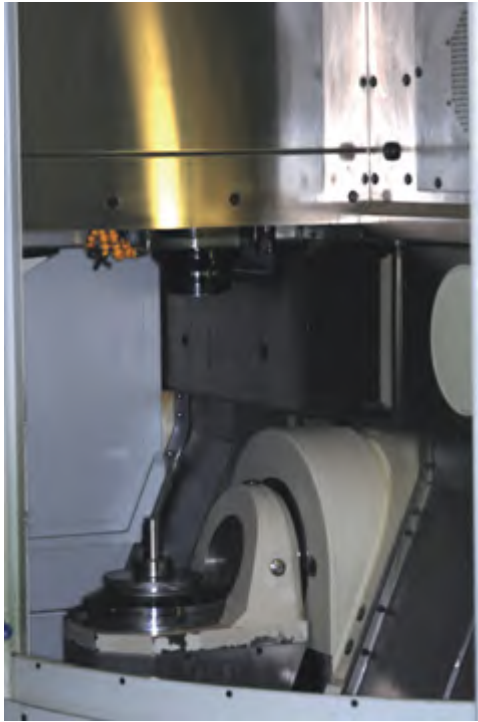


Figure 8.62. Milling unit for Encode Abutments.



Figure 8.63. The four Encode Abutments after milling. At the commercial dental laboratory, the abutment walls were abraded with 100 μ m aluminum oxide. The tooth numbers were ground into the axial walls.

areas of the four stone Encode Healing Abutments in the master cast (Figures 8.64–8.67). The digital data for this were obtained from the original scan of the Encode Healing Abutments in the stone cast.

An implant analog was selected and picked up by the robot, prior to placing into the hole in the stone cast (Figure



Figure 8.64. Laboratory robot that removes the stone in the areas of the stone Encode Healing Abutments by drilling specific-sized holes, consistent with the digital data from the original scan.

8.68). Each analog was placed into and secured to the cast with cyanoacrylate cement (Figures 8.69 and 8.70). This process was repeated for each of the four implant sites (Figure 8.71). Note that a laboratory soft tissue model was not needed because the emergence profile for each abutment had been previously developed in the CAD abutment designs. This process has been proven to be accurate to 0.2mm (Suttin and others 2007).

After both of the CAD/CAM processes were completed for this case, the Final Encode Abutments were placed onto the analogs in the Robocast; both were checked for marginal integrity and contours. Due to the internal connection of these abutments, this step was carried out without using abutment screws. The casts and abutments were packaged and shipped to the prosthodontist's commercial dental laboratory for fabricating the definitive porcelain-fused-to-metal crowns (Figures 8.72–8.74).

FABRICATION OF PORCELAIN-FUSED-TO-METAL CROWNS

The above items were unpacked at the prosthodontist's commercial dental laboratory; the abutments were placed



Figure 8.65. A drill, specific to the implant size and site, in place in the robotic arm, just prior to engaging the stone cast.



Figure 8.66. The drill has engaged the stone cast in the area of the planned analog placement.



Figure 8.67. One hole drilled into a cast, specific to the planned analog site.



Figure 8.68. The appropriate analog (4.1-mm Certain) was picked up by the robotic arm.



Figure 8.69. The analog was placed into its correct 3-D position in the cast by the robotic arm.



Figure 8.71. Occlusal laboratory view of the four implant analogs, in their correct positions, within the stone cast. The two posterior implant analogs represent 5-mm-diameter implants; the two anterior implant analogs represent 4.1-mm-diameter implants.



Figure 8.70. Occlusal laboratory view of two implant analogs in their correct positions within a stone cast. Both analogs were placed by the robot.



Figure 8.72. Buccal laboratory view of the four Final Encode Abutments in place on their respective implant analogs in the Robocast. Some of the stone around the buccal surfaces of the two anterior implant analogs was missing because it had chipped during the drilling process. However, the peri-implant soft tissue margin locations were previously identified in the original scan and transferred to the abutments.



Figure 8.73. Lingual laboratory view of the four Final Encode Abutments in place on their respective implant analogs in the Robocast. Any dental stone that would interfere with the construction of the definitive crowns would be removed by the dental laboratory technician during the crown waxing phase.



Figure 8.74. Occlusal laboratory view of the four Final Encode Abutments in place on their respective implant analogs in the Robocast.



Figure 8.76. Lingual laboratory view of the full-contour wax patterns. Ideal contours were established in wax, consistent with the contours originally made in the diagnostic wax patterns. The wax would be cut back to allow for optimal thickness of porcelain.



Figure 8.75. Laboratory occlusal view of the wax patterns for the definitive porcelain-fused-to-metal crown restorations. The patterns were waxed to full contour. In this image, a silicone index was in place on the lingual aspect of the wax patterns. This allowed the ceramist to more easily transfer the contours established in the wax patterns to the lingual contours of the definitive crown restorations.



Figure 8.77. Buccal laboratory view of the casts in centric occlusion, with the full-contour wax patterns on the mandibular Encode Abutments. Centric stops were waxed into the central fossae and the buccal cusps of the mandibular wax patterns.

onto the analogs with try-in screws. The use of die spacer is a convenient method to overcome problems caused by incomplete crown seating during cementation of a casting whose fit was satisfactory on dies or abutments. In this case, two layers of die spacer were applied approximately 1mm above the cervical margins, directly onto the axial and occlusal surfaces of the abutments.

Full-contour wax patterns were made on the Final Encode Abutments. The wax patterns optimized the axial contours,

occlusal surfaces, and the emergence profiles of each implant restoration (Figures 8.75–8.77) (Burch 1971; Burch and Miller 1973).

The wax patterns were cut back to allow room for porcelain without compromising the integrity and strength of the castings (Figures 8.78 and 8.79). Aesthetic and functional requirements dictated the design of the veneering surfaces. The ceramic veneers were designed to extend far enough interproximal to avoid metal display of the



Figure 8.78. Laboratory occlusal view of the cut back wax patterns; the buccal and lingual silicone indexes were in position. Silicone indexes were made of both the lingual and buccal aspects of the full-contour wax patterns. Approximately 1.7–2 mm of wax was removed from the occlusal and axial surfaces of the wax patterns. The full-contour wax patterns were cut back to provide room for porcelain, without compromising the integrity of the copings. The indexes provided the technician with the necessary information for accurate cutbacks.



Figure 8.79. Laboratory buccal view of the cut back wax patterns with the casts in centric occlusion. The wax patterns were cut back approximately 2 mm on the occlusal surfaces in order to develop optimal aesthetics and functional contours in porcelain.

underlying copings. Aesthetic demands of the patient required the dental laboratory technician to provide porcelain occlusal surfaces for all of the implant crown restorations.

The patterns were cast and finished in preparation for porcelain (Figures 8.80–8.83). Sharp line angles on the veneering surfaces of the metal ceramic restorations were



Figure 8.80. Laboratory image of the cast copings.

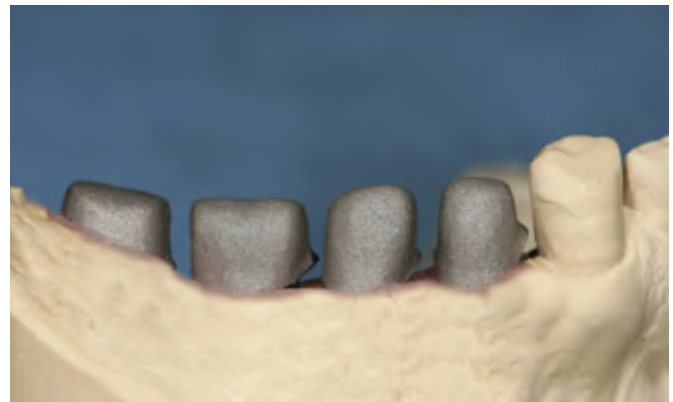


Figure 8.81. Laboratory buccal image of the copings in place on the abutments in the cast.

avoided since they can readily contribute to internal stress within the definitive restorations (Warpeha and Goodkind 1976). Porcelain was stacked in conventional fashion (Figures 8.84–8.86). The crowns were finished, polished, packaged, and returned to the prosthodontist for clinical try-in and insertion (Figures 8.87–8.90).

CLINICAL INSERTION

The patient returned for insertion of the Encode Abutments and porcelain-fused-to-metal crowns (Figure 8.91). The Encode Healing Abutments were removed, and the peri-implant soft tissues had healed consistent with the shapes of the healing abutments (Figure 8.92).

The definitive abutments were placed onto the implants in their respective positions (Figure 8.93). Try-in screws were

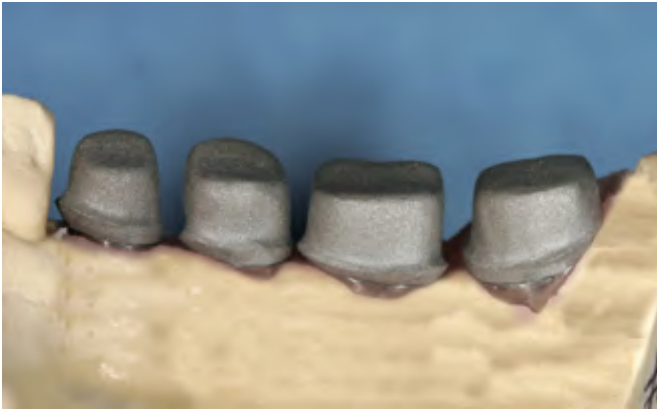


Figure 8.82. Laboratory lingual image of the copings in place on the abutments in the cast.



Figure 8.83. Laboratory occlusal image of the copings and silicone indexes in place on the abutments in the cast. The silicone indexes demonstrated that a uniform, adequate amount of space was provided for porcelain for each of the individual crowns.



Figure 8.84. Laboratory occlusal image of the first application of porcelain on the copings in place on the abutments in the cast. The porcelain was slightly over contoured, consistent with the shrinkage for this porcelain.



Figure 8.86. Laboratory lingual image of the first application of porcelain on the copings in place on the abutments in the cast. The porcelain was slightly over-contoured, consistent with the shrinkage for this porcelain.



Figure 8.85. Laboratory buccal image of the first application of porcelain on the copings in place on the abutments in the cast. The porcelain was slightly over-contoured, consistent with the shrinkage for this porcelain.



Figure 8.87. Laboratory buccal image of the finished porcelain-fused-to-metal crowns, in place on the abutments in the cast. Optimal axial and occlusal contours, along with anatomical emergence profiles, were established in the abutments and crown restorations.



Figure 8.89. Laboratory occlusal image of the finished porcelain-fused-to-metal crowns, in place on the abutments in the cast. The buccal silicone index confirmed that the contours of the definitive crowns were consistent with the contours of the wax patterns.



Figure 8.91. Clinical occlusal view of the patient's presentation at the insertion appointment. The healing abutments remained in place during the interval from the impression appointment to the try-in appointment.



Figure 8.88. Laboratory lingual image of the finished porcelain-fused-to-metal crowns, in place on the abutments in the cast. Optimal axial and occlusal contours, along with anatomical emergence profiles, were established in the abutments and crown restorations.



Figure 8.90. Laboratory buccal image of the articulator mounting with the finished porcelain-fused-to-metal crowns, in place on the abutments. The occlusal contacts and contours were consistent with the contacts and contours established in the full-contour wax patterns.



Figure 8.92. Clinical occlusal view of the implants and peri-implant soft tissues after removal of the healing abutments. The soft tissue contours were consistent with the shapes of the healing abutments; local anesthesia was not needed for this appointment.



Figure 8.93. Clinical buccal image of the Encode Abutments in place. Try-in screws (IUNITS) were used during this part of the procedure (lower left inset).

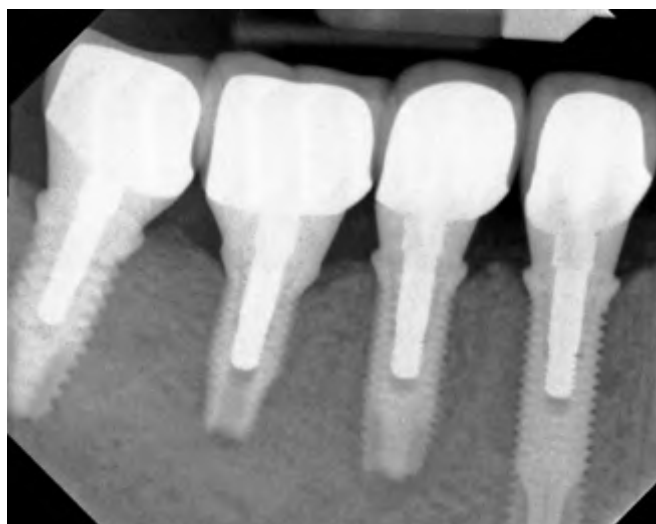


Figure 8.95. Radiograph with the individual implant crowns on their respective four abutments in place demonstrated that the crowns were seated properly onto the abutments. An ill-fitting crown would be identified by a radiolucent space between a crown and an abutment.

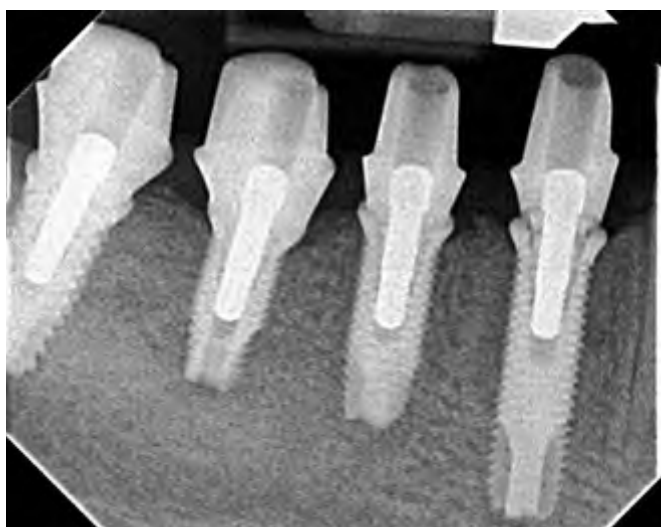


Figure 8.94. Radiograph with the four abutments in place demonstrated that the abutments were seated correctly onto their respective implant restorative platforms. An ill-fitting abutment would be identified by a radiolucent space between an abutment and an implant restorative platform. All of the abutments were made consistent with platform switching.



Figure 8.96. Clinical buccal image with the crowns in place and the patient in centric occlusion. Try-in procedures were accomplished without cement.

used to attach the abutments to the implants (IUNITS, Biomet 3i). A radiograph was taken that verified that all of the abutments were seated correctly onto their respective implant restorative platforms (Figure 8.94). The abutment margins were consistent with the original design: 1 mm subgingival in the interproximal and facial areas and 1 mm supragingival in the lingual areas.

The prosthodontist placed the crowns individually and together and assessed the marginal fit. Interproximal con-

tacts were adjusted until all of the crowns were completely seated onto their respective abutments. Another radiograph was taken that confirmed the crowns were correctly and completely seated onto the abutments (Figure 8.95). The occlusion was evaluated with the patient seated upright and reclined. The occlusion was adjusted so that all of the mandibular buccal cusps were in contact with the opposing central fossae of the maxillary right posterior teeth and that there were centric contacts in the central fossae of the new crowns (Figure 8.96). Right working



Figure 8.97. Clinical occlusal view with the abutments in place. The abutments were connected to the implants with definitive abutment screws (IUNIHG; upper left inset). The screw access openings were blocked out with cotton and restored with light-cured composite resin. The composite resin restorations were contoured such that they did not extend occlusal to the restorative/occlusal interface and thus would not interfere with seating the definitive crowns onto the abutments during cementation.



Figure 8.98. Clinical mandibular occlusal view after the crowns were cemented to the abutments. Optimal form and aesthetics were reestablished with the implants, abutments, and crown restorations.

disclusion was with the maxillary and mandibular cuspid teeth; there were no balancing side contacts when the patient went into a left working position.

The crowns and abutments were removed and the crowns were polished. The abutments were reseated onto the implants and attached to the implants with definitive abutment screws (IUNIHG, Biomet 3i). These screws were

torqued to 20Ncm with a torque instrument. The screw access openings were blocked out with cotton and restored with light-cured composite resin (Figure 8.97). The crowns were cemented to the abutments with temporary cement. The excess cement was removed, and the patient was discharged (Figure 8.98).

The following clinicians and dental laboratory technicians were responsible for the treatments illustrated in this chapter:

Oral Surgeon: Dr. Michael Kuzmik, Tysons Corner, VA

Prosthodontist: Dr. Benjamin Watkins, III, Washington, DC

Dental Laboratory Technicians: John Ezzell: stone work; Patrick Pak: waxing; Kevin Labarge: metal casting and finishing; Rick Bishop: ceramist, Diplomate Dental Lab, Washington, DC

Illustrator: Robin deSomer Pierce, BSMI, Biomet 3i, Palm Beach Gardens, FL

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Chapter 9: Single-Unit Implant-Retained Porcelain Crown with Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) Ceramic Abutment (Encode Zirconia Abutment)

INTRODUCTION

Over the past several decades, the use of computer-aided design/computer-aided manufacturing (CAD/CAM) has been well accepted in industrial manufacturing (Biggs 2000). CAD/CAM has generally resulted in reduced production costs, and this has contributed to decreased personnel costs for commercial industry (Krause 2001). For example, in the automobile industry, industrial robots use a specific computer program to move a specific machine part thousands of times per hour in painting one specific panel of multiple automobiles in a consistent fashion. Dental restorations cannot be made in such a fashion as dental restorations are customized and unique from the beginning to the end of each restoration. Dental manufacturers may have initially underestimated the complexities involved in fabricating custom dental restorations with CAD/CAM protocols. Initially, the original dental CAD/CAM protocols restorations were time and labor intensive; they were not profitable (Duke 2001).

Advances in computer programming, technology, and instrumentation have brought affordable, predictable CAD/CAM protocols to implant dentistry. Designing and milling restorations with this technology give dental laboratory technicians and restorative dentists at least one important advantage: greater accuracy and homogeneity in frameworks and copings than is possible with casting technology or with conventional dental ceramics. Dental manufacturers have adopted some of these new technologies; it has become possible to produce extremely accurate metal and ceramic frameworks for use in implant restorative dentistry (Willer and others 1998; Kerstein and others 2000; Ortorp and others 2003).

Dental CAD/CAM technology was initially developed for single-unit ceramic restorations on natural teeth (Duret and others 1988). Originally, inlays made with this technique demonstrated marginal integrity accuracy of 100–125 μm (Mormann and others 1985). This technology has since been modified and improved for constructing milled titanium frameworks (Mehl and Hickel 2001; Ortorp and others 2003; Popper and others 2003). Biomet 3i (Palm Beach Gardens, FL) manufactures a commercial line of products

using CAD/CAM technology called Architech PSR[®] (Patient Specific Restorations). Titanium blanks may be milled to produce frameworks for edentulous and partially edentulous patients (Figures 9.1 and 9.2). Titanium and zirconia blanks may be milled for custom abutments for use in single- and multiple-unit(s), cement-retained implant restorations (Figures 9.3–9.8).

Patients have increasingly requested metal-free restorations (Reich and others 2005). Due to the successful use of all-ceramic crowns in the anterior and posterior segments of the natural dentition, and with the introduction of advanced dental technology and high-strength ceramic materials, all-ceramic systems have become a viable treatment option for more clinicians and dental laboratory technicians. This type of restoration has also been used for fixed partial dentures (FPDs) in both the natural and implant-restored dentitions (Probster 1996; Oden and others 1998; Fradeani and Redemagni 2002). Ceramic systems must fulfill specific biomechanical requirements and provide similar longevity as preexisting restorations made with metal-ceramic systems. Zirconia, a polycrystalline material without a glassy matrix, is partly stabilized by yttrium oxide and has been studied as an alternative to single- and multiunit metal crown and implant restorations (Vigolo and others 2006).

The use of zirconia ceramics for individual abutments, crowns, and frameworks has been facilitated by the advent of CAD/CAM systems (Tinschert and others 2004; Raigrodski and others 2006). Zirconia, used in the pre-sintered porous (green) state, can be relatively easily machined in a CAM unit (Suttor and others 2001). After machining, the ceramic units have to be densely sintered for 7.5 hours at 1500°C; upon sintering, volumetric changes occur and may lead to linear changes of 15%–30%, along with a subsequent increase in density (Suttor and others 2001). The efficiencies associated with CAD/CAM systems must be weighed against possible inaccuracies resulting from the scanning process, software design, milling, and shrinkage effects.

Zirconia (ZrO_2) is a ceramic material with adequate mechanical properties for manufacturing medical devices

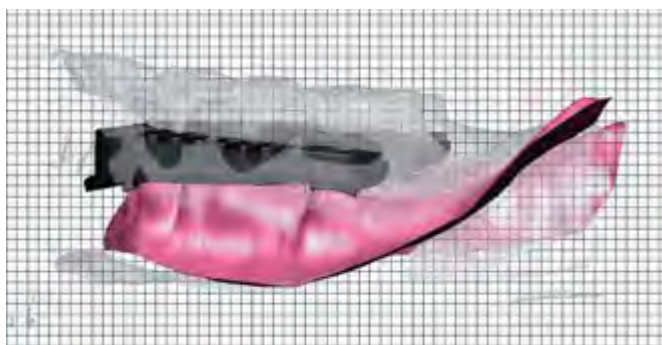


Figure 9.1. CAD image of the left lateral aspect of a mandibular implant-supported framework. Designs such as this are developed by the PSR designers and e-mailed to dental laboratory technicians and/or clinicians for approval prior to milling. The locations of the teeth in the wax denture are visualized, as well as the design of the framework regarding height, thickness, finish lines, and location relative to the soft tissues. If the design warrants changes, the local dental laboratory technician simply calls the designer and explains the requisite changes. Changes are then made and the designs are e-mailed back to the local dental laboratory technician for approval.



Figure 9.2. Laboratory occlusal view of the titanium milled framework designed in Figure 9.1. This framework was milled from a solid blank of titanium alloy per the agreed-upon CAD design discussed above. The gold abutment screws seen in this photograph are actually contraindicated for laboratory use.

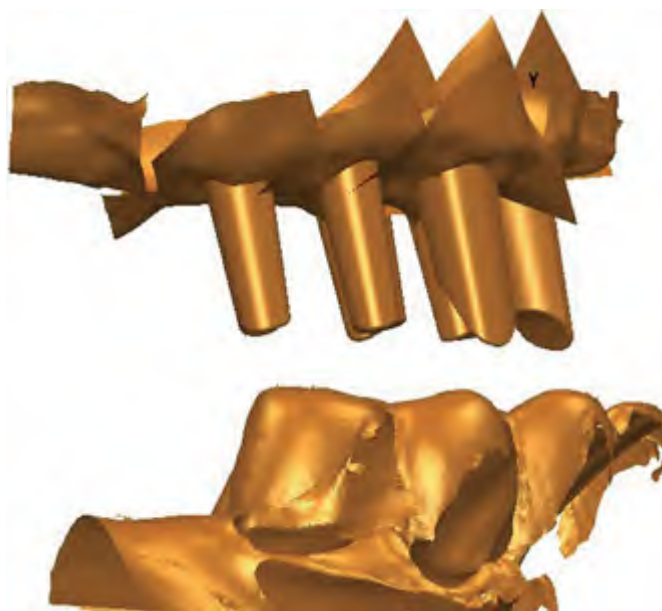


Figure 9.3. Tentative abutment designs for three CAD/CAM Encode Abutments in a maxillary right posterior quadrant. The clinician designed the abutments in conjunction with the local dental laboratory technician regarding parallelism, taper, and margin location/design.



Figure 9.4. Tentative abutment designs for three CAD/CAM Encode Abutments in a maxillary left posterior quadrant. The clinician designed the abutments in conjunction with the local dental laboratory technician regarding parallelism, taper, and margin location/design.



Figure 9.5. Laboratory image of the right buccal surfaces of three CAD/CAM Encode Abutments as designed in Figure 9.3. The abutments were milled as designed by the local dental laboratory technician and PSR designer regarding parallelism, taper, and margin location/design.



Figure 9.6. Laboratory image of the left buccal surfaces of three CAD/CAM Encode Abutments as designed in Figure 9.4. The abutments were milled as designed by the local dental laboratory technician and PSR designer regarding parallelism, taper, and margin location/design.

(Manicone and others 2007). Zirconia, stabilized with Y_2O_3 , has satisfactory properties for these applications. When a stress occurs on a ZrO_2 surface, a crystalline modification opposes the propagation of cracks. Compression resistance of ZrO_2 is about 2000 MPa. Orthopedic research led to this material being proposed for the manufacture of hip head prostheses. Prior to this, zirconia biocompatibility had been studied in vivo, and no adverse responses were reported following the insertion of ZrO_2 samples into bone or



Figure 9.7. Facial surfaces of maxillary and mandibular teeth in occlusion. The maxillary right lateral incisor was missing and was to be replaced with an Encode Zirconia Abutment. The dental laboratory ceramist and clinician designed the abutment in conjunction with the PSR designer regarding parallelism, taper, and margin location/design.



Figure 9.8. Laboratory image of the facial surface of the Encode Zirconia Abutment as designed in Figure 9.7. The abutment was milled as designed by the local dental laboratory technician, clinician, and PSR designer regarding parallelism, taper, and margin location/design.

muscle. In vitro experimentation showed absence of mutations and good viability of cells cultured on this material.

Zirconia cores for FPDs on anterior and posterior teeth, and on implants have been available for a number of years, with few adverse events reported. Zirconia's radiopacity can facilitate clinicians' evaluations of fit between zirconia and metal implant components. Zirconia frameworks can be fabricated with CAD/CAM technology. Cementation of Zr-ceramic restorations can be performed with conventional luting cements.

Mechanical properties of zirconium oxide FPDs have proved superior to those of other metal-free restorations. Sailer and others (2007) reported the results of a prospective clinical cohort study to determine the success rate of three- to five-unit zirconia frameworks for posterior FPDs after 5 years of clinical observation. They reported that the success rate for the zirconia frameworks was 97.8%; however, the survival rate was 73.9% due to other complications (biological). Secondary caries were found in 21.7% of the FPDs, and chipping of the veneering ceramics was found in 15.2%. There were no significant differences between the periodontal parameters of the test and control teeth. Sailer and others (2007) concluded that zirconia offered sufficient stability as a framework material for three- and four-unit posterior FPDs.

High-strength ceramic materials have been used to fabricate aesthetic and stable implant-supported single-tooth restorations. Att and others (2006) evaluated the fracture resistance of single-tooth, implant-supported all-ceramic restorations consisting of alumina all-ceramic restorations on different implant abutments to identify the weakest component of the restorative system. Forty-eight standardized maxillary central incisor alumina crowns (Procera®, Nobel Biocare, Balsberg, Switzerland) were fabricated for each of three groups ($n = 16$) (control group Ti, titanium abutments; group Al, alumina abutments; group Zr, zirconia abutments) for the NobelReplace™ Select (Nobel Biocare) implant system. The crowns were adhesively luted using a resin luting agent and artificially aged through dynamic loading and thermal cycling. Afterward, all specimens were tested for fracture resistance using compressive loads on the palatal surfaces of the crowns. Att and others (2006) reported that all test specimens survived the artificial aging process simulating oral conditions. No screw loosening was recorded. The median fracture resistance was 1454, 422.5, and 443.6N for groups Ti, Al, and Zr, respectively. Significant differences were found for the fracture resistance comparisons of group Ti with groups Al and Zr (Kruskal–Wallis test, $P < 0.001$). The test results between groups Al and Zr were not significant. Att and others (2006) concluded that all three implant-supported restorations could withstand physiological occlusal forces applied in the anterior region.

Zirconia implant abutments can be used to improve the aesthetic outcomes of implant-supported restorations. One-visit, in-office CAD/CAM fabrication of aesthetic ceramic crowns for posterior implants is relatively new. Wolf and others (2008) evaluated the strength of aesthetic ceramic CAD/CAM crowns with varied occlusal thicknesses, seated with adhesive and nonadhesive cements on titanium and zirconia abutments. They fabricated ceramic CAD/CAM molar crowns ($n = 15$ per group) with occlusal thicknesses of 0.5 and 1.5mm, respectively.

The crowns were seated on titanium and zirconia abutments: noncemented (a), with nonadhesive cement (b), or two adhesive resin-based cements (c) and (d). In addition, 15 molar crowns with 5.5-mm occlusal thickness were seated on short zirconia abutments using cements (c) and (d). All crowns had the identical occlusal morphology and were loaded with a crosshead speed of 0.5mm/min until fracture. Load data were analyzed using two-way analysis of variance (ANOVA), the Scheffé test, and Weibull probability of failure analysis. Wolf and others (2008) reported that the fracture loads of the 1.5-mm occlusal thickness crowns (a, b, c, d) were higher ($P < 0.001$) than those of 0.5-mm occlusal thickness crowns (except for the cemented titanium abutments). Occlusal crowns with 5.5-mm thicknesses on the short zirconia abutments had similar (c) or less (d) strength than the respective 1.5-mm crowns. Nonadhesive crowns on titanium and zirconia abutments were weaker ($P < 0.001$) than adhesive crowns (1c, 1d, 2c, 2d). Fracture loads of the 0.5- and 1.5-mm-thick crowns were significantly higher on titanium than on zirconia abutments with both cements. Adhesive cement generally showed higher fracture loads than nonadhesive crowns on both titanium and zirconia abutments. Wolf and others (2008) concluded that ceramic CAD/CAM molar implant crowns possessed greater fracture strengths with adhesive cements on both titanium and zirconia implant abutments compared with nonadhesive cementation.

Misfit of implant components has been linked to restorative complications such as screw loosening and screw fracture. Binon and McHugh (1996) reported the results of a laboratory study where external hexagonal implants of known dimensions were assembled with premachined cast abutments and rebroached cast abutments. The abutment screws were tightened to 20 and 30Ncm, and the samples were loaded off axis with 133.3N. Load application was at 1150 cycles per minute, with a sample counterclockwise rotation of 28 cycles per minute. The premachined cast abutments tightened to 20Ncm failed, with a mean of 357,162 cycles (SD = 77,981 cycles). The rebroached cast abutments were cycled to 1 million cycles without failure. At 30Ncm, the premachined cast abutments failed at a mean of 5.0 million cycles (SD = 2.2×10^6 cycles). Two of five rebroached cast abutments failed at 4.3 million and 9.5 million cycles, but the remaining samples showed no evidence of screw loosening after 10 million cycles, at which time the test was terminated. Binon and McHugh (1996) concluded that there was a direct correlation between rotational misfit and screw loosening. Screw joints can be made more resistant to screw loosening by the elimination of rotational misfit.

Although previous studies have shown a correlation between rotational misfit and screw loosening, information on the impact of casting procedures on rotational misfit is

lacking. Kano and others (2007) reported on the results of an in vitro study that evaluated the effect of casting procedures on rotational misfit of cast abutments when compared with machined titanium abutments. Forty-eight external hexagonal implants and 48 abutments were placed in four groups of 12 samples each: (1) machined titanium abutments; (2) premachined palladium abutments cast-on with palladium; (3) plastic burnout abutments cast with nickel chromium; and (4) plastic burnout abutments cast with cobalt chromium. Rotational misfit between the external hexagon of the implants and the internal hexagons of the abutments were measured using standardized techniques and recorded in degrees. They reported that the mean rotational misfit was 1.21 ± 0.57 degrees for machined titanium abutments, 1.77 ± 1.30 degrees for cast-on abutments, 1.98 ± 0.72 degrees for cast NiCr abutments, and 2.79 ± 1.13 degrees for cast CoCr abutments. Significantly greater rotational misfits were recorded with cast CoCr abutments when compared with machined titanium abutments ($P < 0.05$). Kano and others (2007) concluded that misfit was less than 2 degrees for all groups except for cast CoCr abutments, which demonstrated a significantly greater rotational misfit.

In a study that was published in 2006, Vigolo and others assessed the precision fit at the implant interface of titanium, zirconia, and alumina CAD/CAM Procera abutments with hexagonal connections for single-unit implant restorations. Twenty Procera abutments were manufactured (milled) with commercially pure titanium, 20 with zirconia, and 20 with alumina using CAD/CAM. The rotational freedom of the abutments was assessed to detect the precision of fit of each abutment on the top of the implant hexagon. They found significant differences relative to the rotational freedom between groups: the titanium group and the zirconia group did not differ significantly, but both demonstrated significantly smaller mean rotational freedoms than the alumina group ($P < 0.05$). Rotational freedom was less than 3 degrees for all abutments. Vigolo and others (2006) concluded that the hexagonal misfit of Procera abutments on implant hexagons may be implicated in screw/joint loosening. All of the CAD/CAM Procera abutments consistently showed less than 3 degrees of rotational freedom in a situation where the abutment was connected to an implant by a hexagonal external connection.

Brodbeck published an introduction of the ZiReal® Post (Biomet 3i) in 2003 and reported that restorations in the anterior aesthetic zone presented significant challenges in both the surgical and prosthetic phases of implant dentistry. Brodbeck (2003) wrote that titanium has been established as the material of choice for endosseous implants, resulting in a high degree of predictability. Many types of implants require transmucosal abutments to retain implant

restorations. Ceramics may be the ideal material to replace natural teeth, but at the time of the above paper, Brodbeck (2003) published that most transmucosal abutments were made of titanium. However, ceramics could be used for abutments in implant restorations. Brodbeck (2003) stated that the combination of ceramics for abutments and crowns provided better translucency for implant restorations than was available with metal abutments and porcelain-fused-to-metal crowns. Ceramic abutments and implant restorations also minimized the gray color associated with metal components transmitted through peri-implant tissues. Customized emergence profiles could also be obtained with ceramic abutments; this generally improved the predictability and consistency of the aesthetics obtained in implant restorations.

Per Brodbeck (2003), zirconia as a ceramic material offered not only outstanding material properties but also a well-documented biocompatibility. Brodbeck (2003) reported on cases with existing all-ceramic abutments that resulted in wear of the titanium implant interface, with resulting extrusion of titanium particles into the peri-implant soft tissues. He believed that the metal inserts of ZiReal Posts minimized this, as well as improved the fit between implants and abutments.

Vigolo and others (2005) reported that laboratory processing of implant-supported prostheses may alter the surfaces of the abutments in contact with the implant restorative platforms, with potential repercussions for the implant/abutment interface. The purpose of their study was to assess changes at the implant interface of high-strength zirconia ceramic abutments with hexagonal connections (ZiReal Post) following abutment preparation for single-unit restorations. These abutments were made of the same materials as the new Encode® Zirconia Designer Abutments ceramic abutments. The depth (d) and width (w) of the titanium hexagonal portion of the abutments, the apical diameters of the abutments (D), and the rotational freedom (R) of the abutments were assessed for 20 ZiReal abutments prior to preparation (time 0) and following abutment preparation (time 1) to detect any eventual change of fit of the abutment on the top of the implant hexagon. Vigolo and others (2005) reported that no significant differences relative to any study parameter (d, w, D, and R) were observed between time 0 and time 1 ($P = 0.9542$). Vigolo and others (2005) concluded that misfits between titanium machined ZiReal abutments and implant hexagons may be implicated in screw/joint loosening. They also reported that the results of this study suggested that if all laboratory steps were carefully observed, changes at the implant/ZiReal abutment interfaces did not occur. The maintenance of the original features of the ZiReal Post implant/abutment connection may reduce the risk of screw loosening.

It should be noted that ZiReal abutments were manufactured with titanium inserts for a metal-to-metal fit between ceramic abutments and metal implants.

Few long-term follow-up studies on treatment concepts using CAD/CAM protocols have been reported. Ortorp and Jemt (2004) reported on the results of a type of CAD/CAM protocol called copy milling or computer numeric control (CNC)-milled titanium frameworks. They evaluated the clinical and radiographic performances of implant supported prostheses made with CNC-milled titanium frameworks in edentulous jaws and compared their performances during the first 5 years of function with those of prostheses provided with conventional cast gold alloy frameworks. A consecutive group of 126 edentulous patients were randomly provided with 67 prostheses and titanium frameworks (test group) in 23 maxillary and 44 mandibular jaws. The control group consisted of 62 conventional prostheses with gold alloy castings in 31 maxillary and 31 mandibular jaws. Clinical and radiographic 5-year data were collected for the test and control groups. They reported that the frequency of problems was low, and clinical and radiological performances were similar in both groups. In the test group, the 5-year cumulative survival rates (CSRs) were 94.9% and 98.3% for implants and titanium prostheses, respectively. The respective corresponding CSRs for the control group were 97.9% and 98.2%. More implants were lost post occlusal loading in maxillae in the test group ($P < 0.01$), but this difference was not significant on the patient/prosthesis level ($P > 0.05$). One prosthesis was lost in each group secondary to implant loss. Metal fractures were seen only in the control group (castings), and resin veneer fractures were more frequent in the maxillary prostheses with the gold alloy group ($P < 0.05$). In the test group, the mean marginal bone loss was 0.5 mm (SD = 0.44) in maxillae and 0.4 mm (SD = 0.50) in mandibles. A similar pattern of bone reaction was observed in the control group. Mean marginal bone loss was similar for smokers and nonsmokers ($P > 0.05$). Ortorp and Jemt (2004) concluded that CNC-milled titanium frameworks (CAD/CAM) were a viable alternative to gold alloy castings in edentulous prostheses and presented clinical and radiological performances similar to those of conventional gold alloy frameworks during the first 5 years of function.

CNC-milled frameworks for implant-supported prostheses have been in use for at least the past decade. However, little data have been available on the precision of fit of these frameworks. Eliasson and others (2008) performed a study that evaluated the precision of fit of a CNC-milled framework technique (I-Bridge®, Biomain AB, Helsingborg, Sweden) using Brånemark System (Nobel Biocare AB, Göteborg, Sweden) and NobelReplace (Nobel Biocare AB) system implants. Ten test frameworks were fabricated for one master model for each implant system. Five additional

frameworks were fabricated for five different models simulating clinical cases as controls (Brånemark System). The distortion of implant center point positions was measured in the x, y, and z axes and in three dimensions by using a contact-type coordinate measuring machine and a computer program developed specifically for this purpose. Mann–Whitney *U* test was used to compare differences of distortion within and between the groups. They reported that the maximal distortion in arch width (x axis) and curvature (y axis) was within 71 and 55 µm for all frameworks, respectively. The mean distortion in absolute figures in the x, y, and z axes and three dimensions for “clinical control” frameworks was 23, 26, 4, and 34 µm as compared with less than 12, 12, 2, and 17 µm for Brånemark and NobelReplace™ frameworks, respectively. The control frameworks showed significantly ($P < 0.05$) greater mean and range of distortions in the x and y axes and in three dimensions compared with test frameworks. Eliasson and others (2008) concluded that all frameworks presented signs of misfit, indicating that no framework had a “passive fit.” Frameworks produced in a more routine clinical environment seemed to present greater levels of distortion as compared with frameworks produced in a strict test situation. However, all measured frameworks presented levels of precision of fit within limits considered to be clinically acceptable in earlier studies of frameworks placed on abutments.

Drago reported on the accuracy of the CAD/CAM titanium frameworks manufactured by Biomet 3i (CAM StructSURE® Precision Milled Bars) at the Academy of Osseointegration Annual Scientific Meeting in February 2008. The purpose of the study was to describe a measuring system consisting of laser scanning and computer software programs that measured volumetric differences and compared the degree of misfit between implant titanium frameworks fabricated with a CAD/CAM technology and gold alloy frameworks made with a conventional casting protocol. In this pilot laboratory study, a master cast was used as a “patient” model. This model was scanned as if it were a patient’s jaw. Implant-level impressions and verification indexes were made to construct definitive master casts. A cast gold alloy framework was made on one cast; a titanium milled bar was fabricated with CAD/CAM technology on the second cast. Via a computer software program, the frameworks were scanned and fit onto the original patient scan in a process called lofting. This simulated a virtual one-screw test. This process was repeated on the opposite side. The volumetric differences between the implant restorative platforms of the frameworks and the implant analogs of the patient model were measured to determine the degree of misfit between the frameworks and the analogs of the original patient model.

The titanium milled bar had volumetric differences of 1.4369 and 4.9017 mm³; the cast bar had differences of

9.8960 and 6.2798mm³ for the left and right one-screw tests, respectively. The net differences of 8.4591 and 1.281mm³ demonstrated that the CAD/CAM framework fit better than the cast framework: 8.4591 mm³ and 1.2781 mm³ left and right, respectively. Drago (2008) concluded that based on the results of this pilot, laboratory study, the scanning technology and computer software program demonstrated that the CAD/CAM framework featured in this study was significantly more accurate than a framework cast with a gold alloy and conventional casting technology. Additional laboratory and clinical research is warranted and is being carried out at three different US dental schools.

CAD/CAM PROTOCOL—THE ENCODE® COMPLETE RESTORATIVE SYSTEM

CAD/CAM protocols are available for single-unit implant restorations. Encode® Restorative System (Biomet 3i) is the

proprietary name of the commercial process for fabrication of custom CAD/CAM titanium and zirconia abutments. This process consists of digital scanning of special healing abutment (Encode Healing Abutment) and provides accuracy to 10µm tolerances (*Bioengineering* 2004).

In the Encode® Complete Protocol, Encode Healing Abutments consistent with the size of the teeth being replaced are inserted into the implants. The occlusal surfaces of Encode Healing Abutments have special codes on the occlusal surfaces that identify the implant/abutment connection, the three-dimensional (3-D) orientation of the hex, the diameter of the implant/restorative platform, and the diameter of the healing abutment (Figures 9.9 and 9.10). The dimensions of Encode Healing Abutments replicate the dimensions of traditional healing abutments (Figure 9.11). With this protocol, implant-level impressions are not required. Instead, a definitive crown and bridge type impression is made of the Encode Healing Abutment,



Figure 9.9. Laboratory image of the occlusal surfaces of three Encode Healing Abutments (5, 6, and 7.5 mm diameters; left to right).



Figure 9.10. Clinical occlusal image of an Encode Healing Abutment in place in a maxillary left lateral incisor site. Note that all of the codes were clearly visible on the occlusal surface of the healing abutment.



Figure 9.11. Laboratory image of an Encode Healing Abutment screw, Encode Healing Abutment, and traditional healing abutment (left to right). The traditional healing abutment conveys information to clinicians and dental laboratory technicians via the numbers etched into the occlusal surface. The Encode Healing Abutment conveys information to a computer via the codes embedded into its occlusal surface.

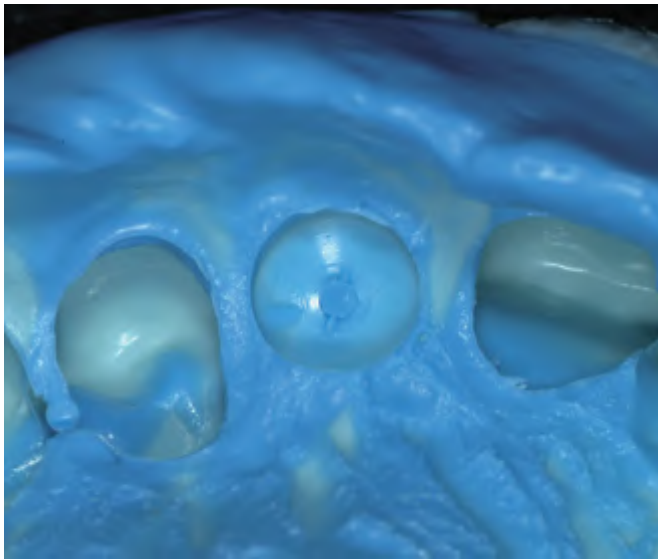


Figure 9.12. The codes of the Encode Healing Abutment in Figure 9.10 were clearly visible in the intaglio surface of this definitive impression.



Figure 9.13. Laboratory image of the die stone occlusal surface of the Encode Healing Abutment in Figure 9.10. The entire occlusal surface of the Encode Healing Abutment was at least 1 mm supragingival and allowed the scanner to record all of the codes without incident.

the adjacent teeth, and the peri-implant tissues (Figure 9.12). By virtue of the impression, the contours of the adjacent soft tissues and teeth were also identified. There may be an additional biological benefit to this procedure. Since there is no need to remove the healing abutment and place an implant impression coping, the peri-implant soft tissues are spared from the insertion and removal of implant restorative components until insertion of the definitive restoration.



Figure 9.14. Laboratory image of the left side of the articulated casts. The occlusal surface of the Encode Healing Abutment stone die had no occlusal contact with the opposing cast.



Figure 9.15. Laboratory image of casts correctly mounted in an articulator with Adesso Magnetic Mounting Plates. The occlusal plane was centered within the articulator, and the casts were centered on the mounting plates. This is a critical step for the scanning procedures to come.

A cast was poured in die stone and mounted on an articulator with magnetic mounting plates, against a cast of the opposing dentition (Figures 9.13–9.15). A work order needs to be completed and signed by a dental laboratory technician (Figure 9.16). The mounted casts and signed work order, not the articulator, were sent to Biomet 3i for scanning and fabrication of the abutment(s).



Figure 9.17. This is the outside of the scanner used in the Encode Restorative System (D-250 3D Scanner).



Figure 9.18. This is the interior of the scanner in Figure 9.17. The mounting plate in the scanner accepts the Adesso Mounting Plates that casts have been mounted with in order to fabricate a definitive Encode Abutment.

This restorative protocol was explained in Chapter 4. In review, the cast with the Encode Healing Abutment (in stone) is scanned. The computer software program interprets the codes and records the specifics of the implant, dental and gingival architectures. The digital data are sent to PSR designers for design of the definitive Encode Abutment, as well as to the laboratory for fabrication of the Robocast (Biomet 3i). Robocast technology involves removal of the stone in the area of the planned implant analog and placement of the appropriate implant lab analog into the cast by virtue of the digital data obtained from the scan of the Encode Healing Abutment cast.

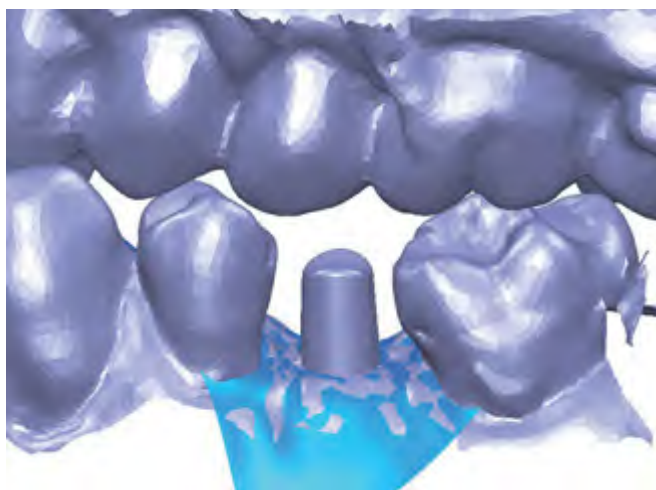


Figure 9.19. This is an example of an abutment design for a single definitive Encode Abutment (titanium alloy) that was sent from PSR to a commercial dental laboratory for review. In this case, the margins were designed to be circumferentially subgingival.

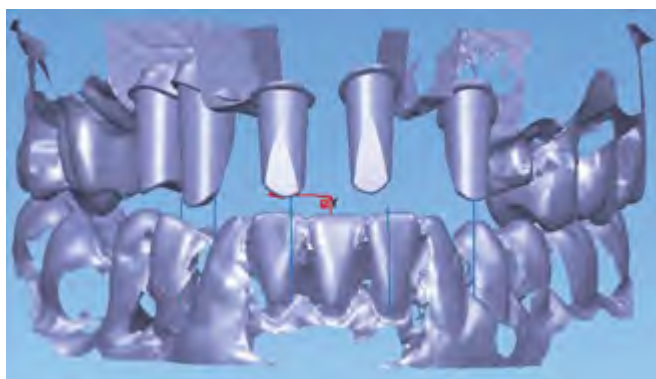


Figure 9.20. This is an image regarding the construction of multiple Encode Abutments to replace multiple, missing maxillary anterior teeth. Dental technicians may provide design changes to the abutment designs prior to milling.

Robocast technology requires that the original die stone cast, on the original articulator mounting plate, be placed into the robot mount. The robot removes the stone in the indicated area and then positions the implant lab analog into the cast. The analog is cemented into place with cyanoacrylate cement. The implant analog now replicates the implant position in the patient. This results in fabrication of a Robocast, which the commercial dental laboratory uses to fabricate the definitive restoration.

The casts were scanned (Figures 9.17 and 9.18). The computer recognized the codes on the abutment as described above. A CAD/CAM abutment was then designed by PSR technicians (Figures 9.19–9.21). Encode Abutments can now be fabricated from titanium alloy or

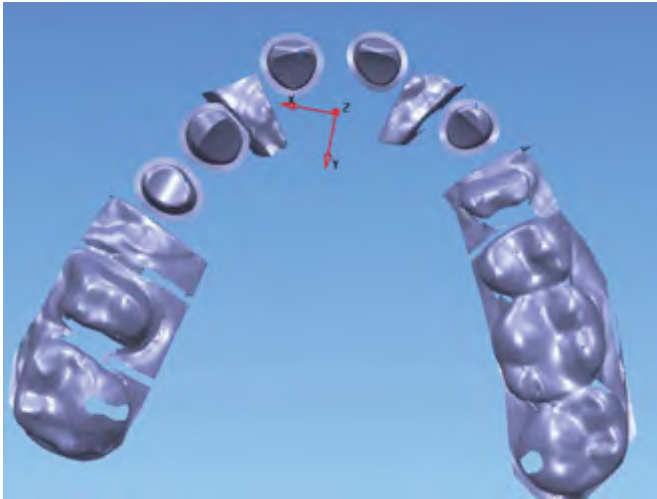


Figure 9.21. This is an image (occlusal view) of the case illustrated in Figure 9.20. The designs may be altered relative to total occlusal convergence, location of abutment margins, locations for two- and three-plane reductions, and so on, prior to milling.



Figure 9.23. These illustrations represent the contours of definitive Encode Zirconia Abutments. The implant/abutment connection was machined within a blank of zirconia. The abutment is a one-piece design made entirely from a zirconia blank. Unlike other Certain Abutments, this abutment does not have any retention fingers. Therefore, a “click” will not be appreciated by laboratory technicians or clinicians when these abutments are seated.



Figure 9.22. Laboratory images of a definitive Encode Abutment. This abutment was treated with a gold titanium nitride coating to eliminate the silver/gray metal color of the titanium alloy abutment. This surface treatment “warms” the color of the abutment as it traverses the peri-implant soft tissues and improves the aesthetic result, especially in thin, translucent tissue. The left image is the palatal portion of the abutment; the right image is the mesial portion of the abutment. The emergence profile of the abutment was designed in the computer, consistent with the anatomy of the missing tooth; the abutment was milled consistent with the design that was agreed upon by the dental laboratory technician, clinician, and PSR designer.

zirconia. These data are sent to the milling unit for fabrication of the abutment (Figures 9.22 and 9.23). The abutment and casts are returned to the commercial dental laboratory for fabrication of the definitive crown.

To date, there are no published articles on Encode Zirconia Abutments. There have been several articles published on titanium Encode Abutments (Drago 2006; Drago and Peterson 2007; Peterson and Drago 2007).

CLINICAL PATIENT PRESENTATION

A 45-year-old male presented to the periodontist with a chief complaint, “My front tooth is loose. I don’t want a bridge.” This tooth had been treated endodontically approximately 5 years previously (Figure 9.24).

The patient presented with no medical contraindications for outpatient surgery. His medical and dental histories were essentially negative.

Preoperative radiographs demonstrated a horizontal root fracture in the apical third of the root. The root was of such a size that there appeared to be adequate bone volume

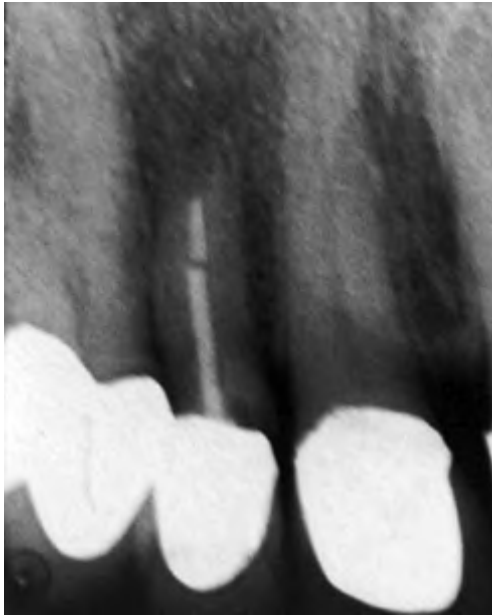


Figure 9.24. Preoperative periapical radiograph of the maxillary right lateral incisor prior to extraction. There was a horizontal root fracture approximately in the middle third of the root.



Figure 9.26. A 4-mm-diameter implant has been placed over the fractured root in this periapical radiograph. This demonstrates that there was adequate bone volume for placement of a 4 × 11.5 mm implant that will replace the maxillary right lateral incisor.

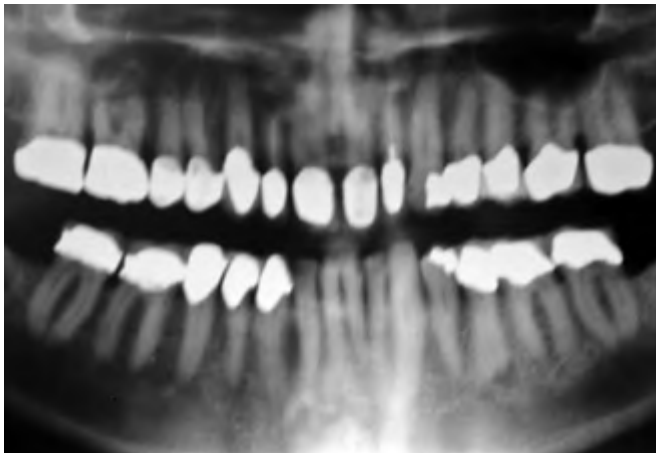


Figure 9.25. The original panoramic radiograph prior to the extraction of the maxillary right lateral incisor.

for placement of a 4-mm-diameter implant; there was no osseous pathology (Figures 9.25 and 9.26).

The physical examination was significant for mild gingival inflammation; no occlusal problems were noted. His occlusion appeared to be stable. He was caries free, with numerous restorations; his dentition was well main-



Figure 9.27. Clinical image of the patient during speaking. The patient had a relatively low lip line, in that the cervical portion of the existing tooth was not visible during speech. This type of anatomical situation provides clinicians and laboratory technicians more leeway in terms of having to generate “perfect” aesthetic results.

tained. He appeared to have adequate space for an implant-retained crown in the area of the maxillary right lateral incisor. None of the gingival tissues in the area of the maxillary right lateral incisor were exposed while smiling, talking, or at rest (Figures 9.27 and 9.28).



Figure 9.28. Clinical profile image of the patient in centric occlusion. The patient presented with an adequate vertical dimension of occlusion.

DIAGNOSIS

The following diagnoses were made:

1. Partially edentulous maxilla
2. Adequate bone volume for placement of a 4-mm-diameter implant in the maxillary right lateral incisor edentulous area
3. Adequate restorative volume for restoration of the implant with an anatomically shaped lateral incisor implant-retained crown
4. Adequate band of fixed keratinized tissue for an implant restoration

ASSESSMENT

The patient appeared to be an excellent candidate for placement of a 4-mm-diameter tapered implant and implant-retained crown restoration. Top-down treatment planning is a protocol where the desired restorative result is considered first in treatment planning (Lazzara 1994) (Figure 9.29). Clinicians should consider the size of the ideal implant restorative platform for a given situation; subsequent implant selection is based on the amount of available bone. The top-down treatment planning protocol provides for maximum biomechanical implant stability by utilizing an implant with an implant restorative platform consistent with the size of the tooth being replaced.

Top-down treatment planning allows clinicians to match the size of the prosthetic platform to the restoration it will eventually support while allowing for different bone volumes



Figure 9.29. This is an illustration of top-down treatment planning, where the desired restorative result for the missing tooth and implant restoration are considered first in treatment planning. This ideally leads to the consideration of the ideal implant restorative platform for a given situation and subsequent implant length and diameter selections based on the bony anatomy. In this case, a 4.1-mm-diameter implant was selected to replace the missing right maxillary right lateral incisor.

and anatomical features at the implant site. Implant and healing abutment selections are based on the relationship of the following anatomical variables:

- The emerging dimension of the crown in relation to the diameter of the implant restorative platform (Figure 9.30)
- The height and diameter of the intended restoration as it exits the peri-implant soft tissues (Figures 9.31 and 9.32)
- The bone volume at the implant site in relation to the diameter of the implant body (Figure 9.33)

Since the patient was not using any type of provisional prosthesis, a diagnostic wax pattern was made on the diagnostic cast for the patient's aesthetic approval (Figure 9.34). Implant placement and fabrication of a provisional crown per an immediate nonocclusal loading protocol were not important for this patient; this surgical/restorative protocol was not offered to the patient (Drago and Lazzara 2004). If the implant achieved an insertion torque value of at least 30Ncm, and the patient did not need any additional bone grafting, the periodontist planned on using a one-stage surgical protocol. If these criteria are met,



Figure 9.30. Illustration of the top-down treatment planning protocol. The patient in this photograph was missing the maxillary incisors. One potential treatment option involved the placement of 3.4-mm-diameter implants in the lateral incisor edentulous sites and 4.1-mm-diameter implants in the central incisor sites. These diameters would provide for optimal interimplant clearances, hopefully maintain the interproximal bone, and result in an acceptable aesthetic result regarding the gingival interdental papillae. The restorative platforms would also allow development of implant restorations with emergence profiles consistent with the missing teeth.



Figure 9.31. Illustration of the top-down treatment planning protocol regarding implant and healing abutment diameters. If custom provisional fixed restorations are not planned in a given clinical situation, clinicians may place stock healing abutments consistent with the size and shape of the teeth being replaced with implant restorations. In this illustration, the maxillary lateral incisors would be restored with healing abutments of 5-mm emergence profile diameters; the maxillary central incisors would be restored with healing abutments of 6-mm emergence profile diameters. The healing abutments in this illustration are Encode Healing Abutments.



Figure 9.32. These healing abutments were manufactured with similar dimensions: 6-mm emergence profile diameters, 4-mm collar heights, 4.1-mm implant restorative platforms. The healing abutment on the left is an Encode Healing Abutment for an internal connection implant; the healing abutment on the right is a conventional, one-piece healing abutment for an external connection implant.



Figure 9.33. This is an illustration where a 4.1-mm-diameter implant was required, and the requisite space was available, to replace a maxillary lateral incisor.

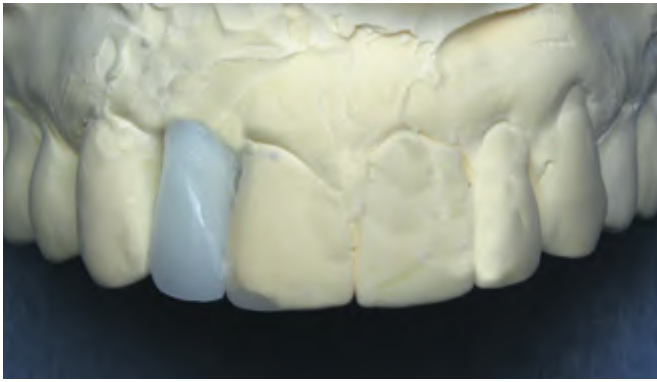


Figure 9.34. Laboratory image of the diagnostic wax pattern for the maxillary right lateral incisor on the diagnostic cast. The cast was duplicated, and a surgical guide was fabricated prior to the surgery.



Figure 9.35. Labial clinical image of the maxillary right lateral incisor edentulous site. A conventional, one-piece healing abutment (4-mm tall, 5-mm emergence profile, and 4.1-mm implant restorative platform [THA454, upper left inset]) would be ideal for use in this situation as it came closest to matching the cervical dimensions of the missing natural tooth.

one-stage surgical protocols have proven to be as efficacious as two-stage surgical protocols (Testori and others 2002; Galli and others 2008).

The Emergence Profile (EP®) Healing Abutment System (Biomet 3i) provides healing abutments designed and manufactured with different diameters and heights, consistent with the size of the teeth being replaced. This system allows for shaping the peri-implant soft tissues to replicate the geometry and gingival contours of the natural dentition (EP Healing Abutments). In this case, a 5-mm healing abutment was selected consistent with the top-down treatment planning approach (Figure 9.35). This patient wanted the maximum aesthetic result that was pos-



Figure 9.36. Clinical image of the labial surface of an implant-retained all-ceramic crown cemented onto a ceramic abutment replacing the maxillary left lateral incisor. Due to the ceramic white-colored abutment, there was no hint of metal show through of the thin peri-implant tissues that surrounded the maxillary left lateral incisor implant.



Figure 9.37. Laboratory anterior view of the mounted diagnostic casts.

sible; therefore, the periodontist planned on using the Encode Complete Restorative System with a CAD/CAM zirconia abutment (Figure 9.36).

DIAGNOSTIC CASTS/SURGICAL GUIDE

Alginate impressions were made of the dentitions; diagnostic casts were poured in dental stone (Figures 9.37 and 9.38).

The periodontist sent the casts to a commercial dental laboratory and had diagnostic wax patterns fabricated based on the planned position of the right maxillary right lateral incisor, as well as other anterior restorations (Figure 9.39). His dental laboratory technician made a surgical guide and placed a stent guide tube (SGT25, Biomet 3i)

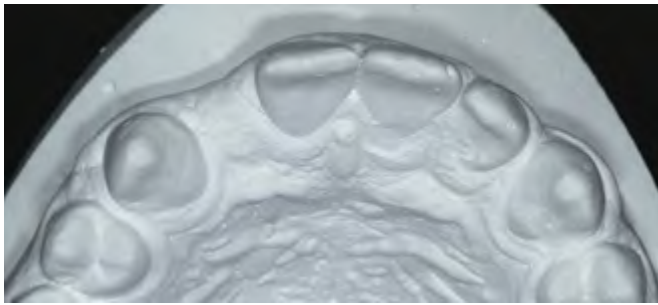


Figure 9.38. Laboratory occlusal view of the maxillary diagnostic cast.



Figure 9.39. Laboratory right lateral facial view of diagnostic wax patterns on the maxillary diagnostic cast. The wax patterns aided the technician and restorative dentist in determining the optimal sizes for the teeth in the maxillary anterior segment. This cast was duplicated prior to fabricating the surgical guide.

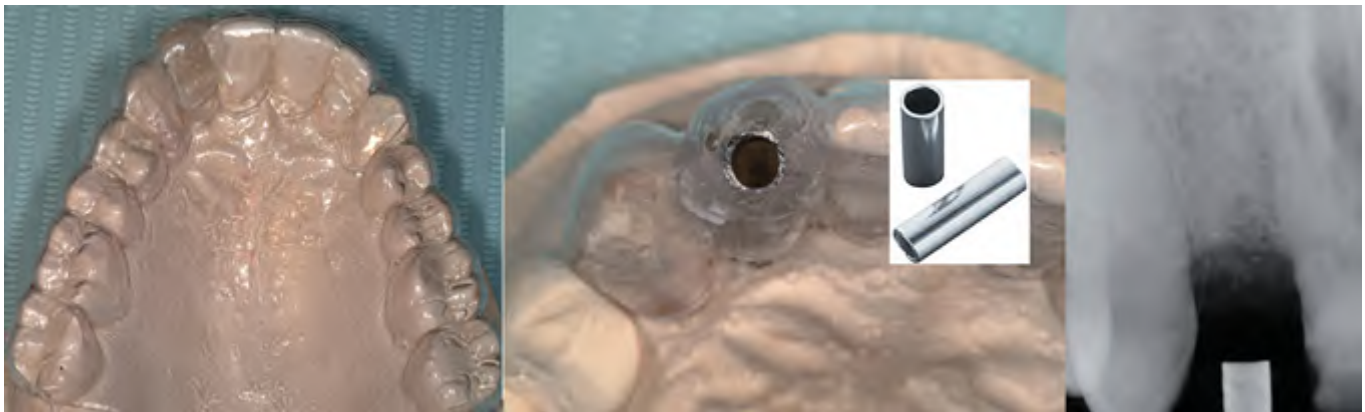


Figure 9.40. Laboratory occlusal view of the maxillary cast with the surgical guide in place (left). The periodontist placed the stent guide tube (SGT25; inset) into the surgical guide in a specific location based on the results of the clinical and radiographic examinations, as well as the optimal location of the planned implant restoration (center). Periapical radiograph of the maxillary right lateral incisor edentulous site with the surgical guide in place (right).

into the surgical guide. It must be noted that the guide tube was placed based on the anatomy of the teeth and hard/soft tissues of the diagnostic cast and two-dimensional radiographs. It provided the periodontist with a starting point for the osteotomy. However, the exact location of the osteotomy could be modified based on the specific anatomy of the implant site. He took a radiograph with the surgical guide in place, approved the tentative position of the implant, and scheduled the patient for the implant surgery (Figure 9.40).

IMPLANT SURGERY

A 4-mm tapered implant (NanoTite™ Tapered Certain®, NINT411, Biomet 3i) was placed. In the presence of adequate attached gingiva and to decrease the morbidity

associated with the surgical procedure, a flapless protocol was used (Figures 9.41–9.43). The insertion torque registered 35 Ncm on the implant drilling unit. Therefore, a one-stage surgical protocol was used.

PLACEMENT OF ENCODE HEALING ABUTMENT

To facilitate the implant restoration for the referring general dentist, the periodontist decided that a custom CAD/CAM abutment would be the treatment of choice for the maxillary right lateral incisor implant restoration. This decision was based on ease of use for the general dentist as well as the benefits associated with a ceramic CAD/CAM abutment.

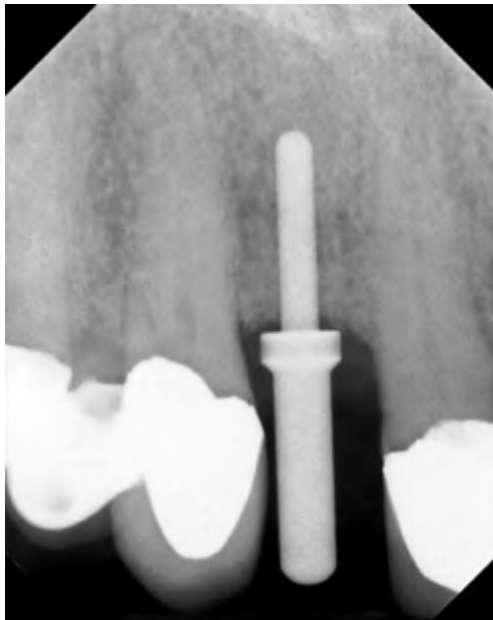


Figure 9.41. Periapical radiograph of the maxillary right lateral incisor edentulous site with the direction indicator in place. This radiograph was taken after the first drill was used and identified the orientation of the osteotomy.



Figure 9.43. Periapical radiograph of the implant immediately after the healing abutment was placed. The periodontist selected the healing abutment consistent with the cervical diameter of the missing maxillary right lateral incisor. This radiograph confirmed that the healing abutment was completely seated onto the implant restorative platform. Incomplete seating would require the periodontist to remove the healing abutment from the implant, remove the hard or soft tissue interferences, and reseal the healing abutment. If profiling was accomplished, another radiograph would be needed to ensure that the healing abutment was completely seated onto the implant.

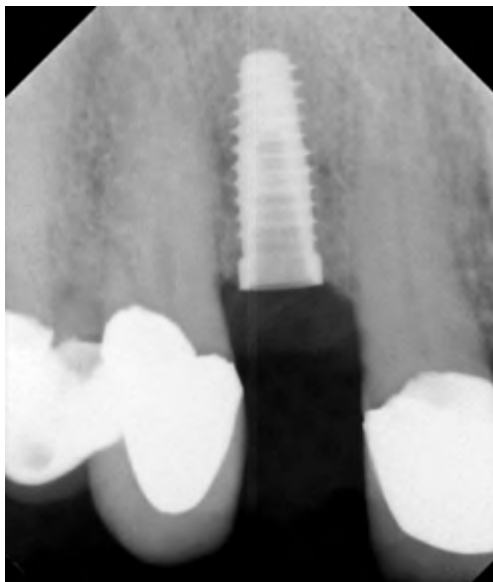


Figure 9.42. Periapical radiograph of the implant immediately after it was placed into the osteotomy. The periodontist placed the implant at the level of the osseous crest. The implant obtained an insertion torque value of 35 Ncm.

A unique healing abutment (Encode Healing Abutment) was selected consistent with the top-down treatment planning approach: 5-mm emergence profile diameter, 4-mm collar height, 4-mm implant diameter, internal connection implant (IEHA454, Biomet 3i) (Lazzara 1994) (Figures 9.44 and 9.45). These dimensions were consistent with the cervical diameter of a maxillary lateral incisor (Figure 9.46).

The height of an Encode Healing Abutment, as compared with the height of a conventional healing abutment, has to be taller in order to accurately scan the occlusal codes, as clinicians must be able to visualize all of the codes on the occlusal and axial surfaces of Encode Healing Abutments. The heights of the occlusal portions of Encode Healing Abutments must be located at least 1 mm above the gingival margins around each of the healing abutments because parts of the codes extend slightly onto the axial walls of the Encode Healing Abutments (Figure 9.47).

Encode Healing Abutments consist of two pieces: the abutment screw with a large hex (0.048in) and the abutment body. The bodies of these healing abutments were



Figure 9.44. Clinical labial image of the Encode Healing Abutment in place prior to patient discharge. The implant was placed with a flapless procedure.



Figure 9.46. This illustration demonstrates the implant and healing abutment that were used in this chapter's treatment: 4.1-mm-diameter implant with an internal connection, placed approximately 3 mm apical to the gingival margins of the adjacent teeth; 5-mm emergence profile Encode Healing Abutment in place on the implant.



Figure 9.45. Clinical occlusal image of the Encode Healing Abutment in place prior to patient discharge. The implant was placed with a flapless procedure.



Figure 9.47. Clinical occlusal image of two Encode Healing Abutments in place in a maxillary left posterior quadrant. All of the codes on the occlusal surfaces of the healing abutments were supragingival and could be scanned accurately.

designed with a hex interface to engage the hex connections of implants (Biomet 3i's internal connection; 4.1-mm external hex). Proper seating of the healing abutment must be verified with radiographs (Figure 9.48). The abutment screw was tightened to 20Ncm with a torque indicator prior to discharging the patient.

Approximately 10 weeks post implant placement, the peri-implant soft tissues had healed, the patient was asymptomatic, and the implant was considered to be osseointegrated (Figures 9.49 and 9.50).

A definitive impression was made of the healing abutment, in a full-arch stock tray, with polyvinyl siloxane impression material (Figure 9.51). After the impression material set, the impression tray was removed from the mouth, and the impression was examined to verify that an accurate impression had been made of the Encode Healing Abutment occlusal codes, including the entire circumferences of the healing abutment, as well as the soft tissue contours. The definitive maxillary Encode Healing Abutment impression and the mandibular diagnostic cast were sent to the commercial dental laboratory for fabricating the

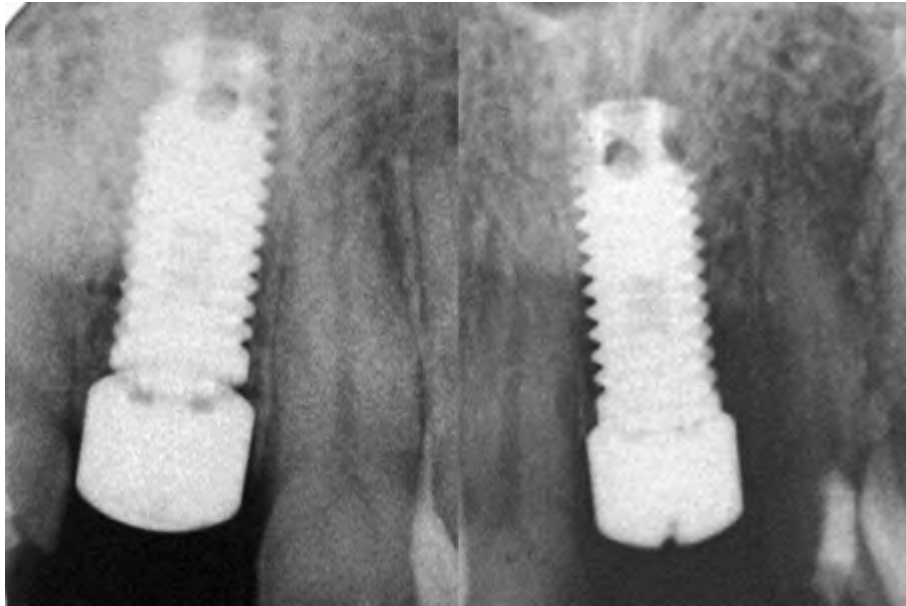


Figure 9.48. The left periapical radiograph demonstrates that the healing abutment was not seated accurately and completely onto the implant restorative platform. The healing abutment was removed from the implant, the soft and hard tissue interferences were removed with profiling instruments, and the healing abutment was resealed accurately and completely onto the implant restorative platform. Accurate seating was demonstrated on the right periapical radiograph.



Figure 9.49. Clinical occlusal image of the Encode Healing Abutment in place approximately 10 weeks post implant placement. The peri-implant soft tissues had healed, the abutment was highly polished, and the implant/abutment connection and implant were stable. The implant was considered to be osseointegrated.

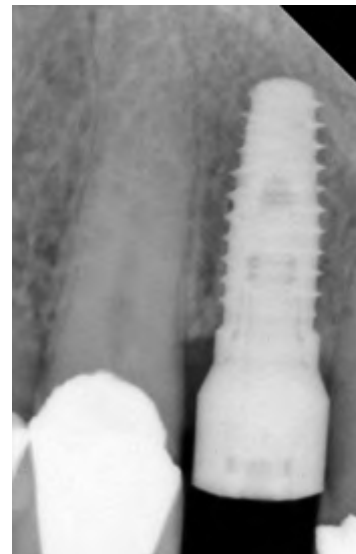


Figure 9.50. Periapical radiograph 10 weeks post implant placement. There appeared to be good bony adaptation around the entire circumference of the implant, without any radiolucencies. There was no pathology; the patient was ready to proceed with the definitive impression.

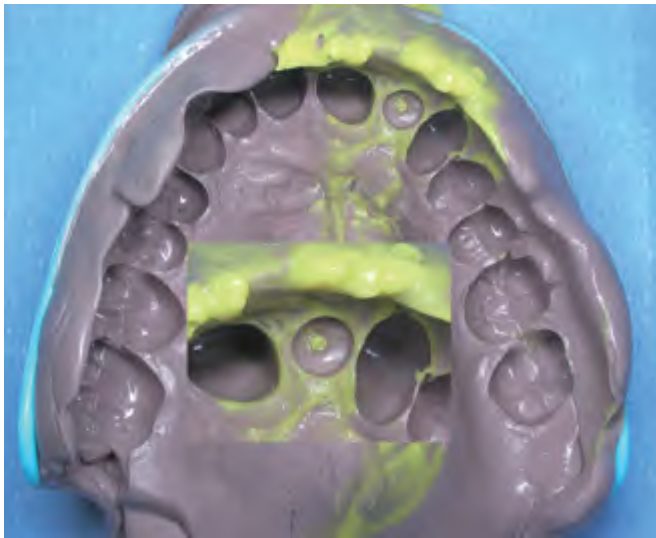


Figure 9.51. Laboratory image of the full-arch impression with polyvinyl siloxane impression material. The inset is a close-up image of the Encode Healing Abutment impression.



Figure 9.52. Laboratory occlusal image of the full-arch diagnostic cast. Full-arch casts are easier and more predictable to mount than quadrant casts.

maxillary master cast, articulator mounting, and completion of the work order for fabrication of the Encode Zirconia Abutment.

MASTER CAST

At the commercial dental laboratory, the impression was poured with low-expansion die stone per the manufacturer's instructions (Figure 9.52). Master casts must be thick enough to allow for insertion of the appropriate implant analog.

The cast was carefully inspected to verify that all of the occlusal codes were replicated from the impression (Figure 9.53). For accurate scanning, Encode Healing Abutment casts must provide the following:

1. Complete visibility of the occlusal surfaces (defect free)
2. One-millimeter visibility of the axial walls
3. Accurate and defect-free duplication of the peri-implant soft tissues around each healing abutment

For this particular protocol, the implant analog was to be placed with robotic technology; therefore, the cast was poured as one solid cast. With robotic analog placement, dowel pins cannot be placed into casts as with an implant-level impression/crown and bridge protocol. Therefore, casts made for use with this protocol have to be solid, including the cast base. Plates also cannot be used per this robotic analog placement technology (Figure 9.54).



Figure 9.53. Close-up occlusal laboratory image of the Encode Healing Abutment in die stone. The clinical codes were replicated in die stone.

ARTICULATOR MOUNTING

The casts were hand articulated and mounted on an articulator compatible with Adesso® Split Mounting Plates (Baumann Dental GmbH, Ellmendingen, Germany), such as the Ivoclar Stratos™ 100 (Ivoclar Vivadent, Amherst, NY) (Figure 9.55). Prior to mounting the casts, the articulator at the commercial dental laboratory was calibrated and zeroed per the manufacturer's instructions; it is imperative to make sure the vertical occlusal pin is set at zero and rests on the incisal guide table. The articulator

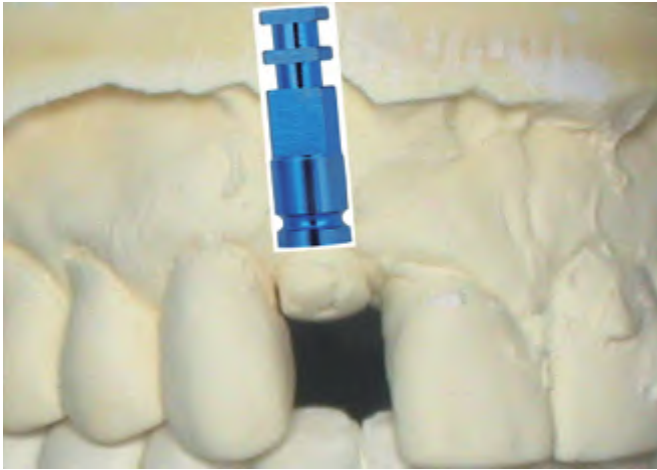


Figure 9.54. Laboratory image of the full-arch cast. The cast must be thick enough for the robot to drill a hole large enough to allow placement of the appropriate implant lab analog into its correct position. A 4.1-mm implant lab analog has been superimposed over the base of the cast to illustrate this point.



Figure 9.55. Laboratory lateral view of the casts for this case mounted in the Stratos 100 articulator. The occlusal plane was centered vertically between the upper and lower members of the articulator; the casts were mounted directly in line with the mounting plates.

was adjusted with the patented centering key. The manufacturer has stated that, when adjusted properly, the Adesso Split System has micrometer accuracy between articulators (www.modelsystem-2000.com/english/pdf/prospekte/e_26660.pdf).

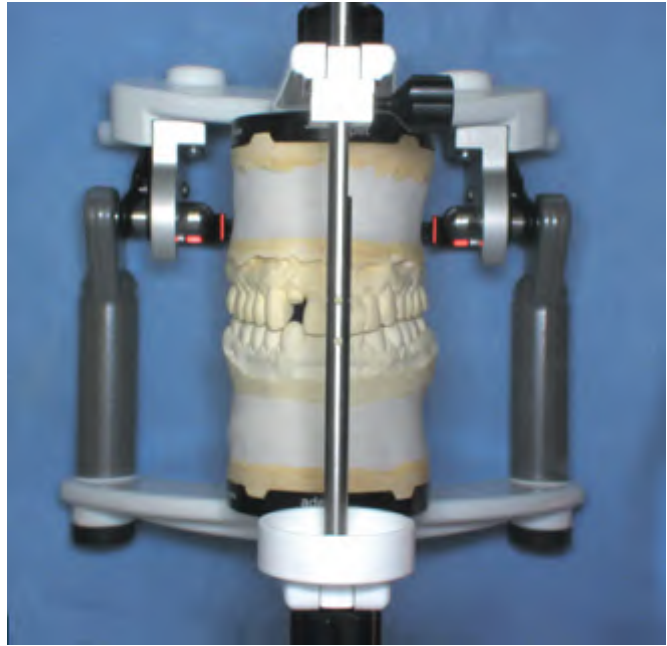


Figure 9.56. Laboratory anterior view of the casts for this case mounted in the Stratos 100 articulator. The occlusal plane was centered vertically between the upper and lower members of the articulator; the maxillary midline was centered within the incisal guide pin.

The casts were centered within the articulator with the incisal edges of the maxillary anterior teeth aligned with the horizontal pin on the incisal guide pin. Casts must be centered on the mounting plates since the scanners read the casts relative to where the plates were located in the articulator. If a cast is not centered within the mounting plates, the cast and healing abutments will not be correctly scanned (Figure 9.56). The incisal guide pin was set to zero.

ENCODE COMPLETE WORK ORDER

The work order was completed and signed by the dental laboratory technician (Figure 9.57). In this case, the dental laboratory technician specified the following:

1. The implant site by tooth number
2. The implant abutment connection as Certain
3. The abutment was to be an Encode Zirconia Abutment
4. The implant site should have the implant analog placed by the robot
5. Chamfer margins
6. The facial and interproximal margins were to be placed 1 mm subgingival

Work Order

* 1. Account Information

* Laboratory Name: _____

BIOMET **3i** Account#: _____

* Contact: _____

* Phone: _____

Fax: _____

* Email: _____

* Patient ID: _____

* Ship To: _____

Bill To: _____

* 2. Preparing Your Case For Shipment

- Use only die stone for Encode Complete Casts
- Verify that all of the codes on each healing abutment are completely visible on the cast
- Mount casts on Adesso Split Plates Articulator **only** (Stratos® or Baumann) and verify the vertical pin is set at zero and meets the occlusal table
- Following mounting on the designated articulator, please include the following in the shipment to BIOMET 3i:
 - ☐ Encode Cast
 - ☐ Opposing cast
 - ☐ Copy of the completed work order
- All unarticulated or misarticulated casts will be returned to the laboratory
- Please **do not** send the articulator
- Analogs cannot be placed in sectioned or pinned casts
- **Please make sure there is no metal in the cast.** The laboratory is responsible for any damage to BIOMET 3i Equipment or personnel caused by metal in the cast

* 3. Case Information

[illegible]

**** NOTE:** TiN Coating will add two working days to the processing of your abutment. If a box is not checked the abutment will not be TiN coated.

* 4. Design Guidelines

Margin Style – Select One

- ☐ Shoulder
- ☐ Chamfer (default)

Interocclusal Distance: _____ mm.

NOTE: Default on all margins = 1mm Subgingival

* REQUIRED FIELD

Buccal Margin Location

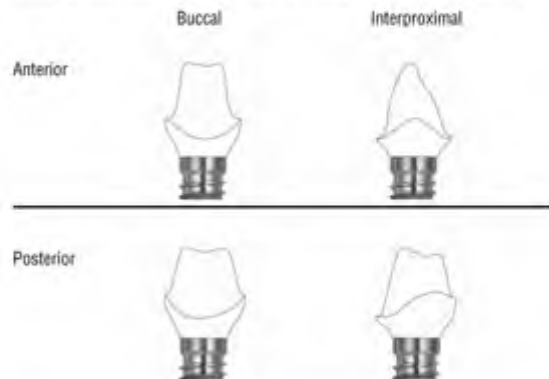
- ☐ Subgingival _____mm
☐ Flush with gingiva

Lingual Margin Location

- ☐ Subgingival _____ mm
☐ Flush with gingiva
☐ Supragingival _____ mm

5. Contour Guidelines

Please draw the approximate contour desired over the default images below.
Note margin style. Please draw in tissue contour.
(Minimum abutment height = 4mm and minimum collar height = .5mm)



6. Special Instructions

- ☒ Polish entire abutment (default) ☐ Only polish the subgingival collar

- ☐ See back or attached page for additional instructions

7. Screw Ordering

- ☐ I would not like to order screws at this time.

<u>Certain Abutment Screws</u>	<u>Qty.</u>
Gold-Tite® Hexed (IUNIHG)	_____
Titanium Hexed (IUNIHT)	_____
Laboratory Hexed Try-in Screw - 5 pack (IUNIT5)	_____

External Hex Abutment Screws	Qty.
Gold-Tite Square (UNISS)	
Gold-Tite Hexed (UNIHG)	
Titanium Hexed (UNIHT)	
Laboratory Square Try-in Screw - 5 pack (UNITS)	
Microminiplant™ Square Try-in Screw - 5 pack (MUNITTS)	

* 8. Certification — must be signed

I certify that the stated information is correct and that the submitted materials are accurate and contain no metal. All items that have contacted the oral environment have been disinfected. This form authorizes BIOMET 3i to fabricate the patient specific abutment(s) and place analogs using and consistent with the information provided on this work order.

Technician Signature _____

Date _____

Internal Use Only

Job #: _____

Signature: _____

BIOMET 3i

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Figure 9.57. Work order for the Encode Zirconia Abutment and robotic analog placement.

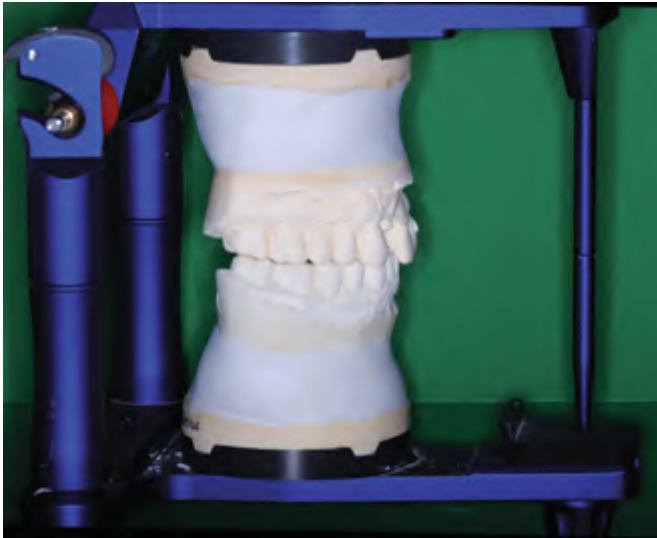


Figure 9.58. The casts and mounting plates were placed onto the articulator at Biomet 3i for verification of the mounting. The casts articulated in the same relationship that was established at the commercial dental laboratory; the incisal guide pin rested on the incisal guide table, and the mounting was considered to be accurate. The casts were scheduled for scanning.

7. The lingual margins were to be placed 1mm supragingival
8. The interocclusal distance between the palatal surface of the abutment and the incisal edge of the opposing tooth was to be 2mm
9. The contour guidelines were to be standard
10. The abutment was to be polished
11. Robotic placement of the analog, consistent with the Encode Healing Abutment in the cast

The casts and mountings were carefully wrapped in bubble paper and sent to the Patient Specific Products (PSP) Department, Biomet 3i, 4555 Riverside Drive, Palm Beach Gardens, FL.

SCANNING

The casts were received at Biomet 3i and placed onto the articulator for verification. This articulator is verified on a daily basis. The original articulator mounting was considered to be accurate (Figure 9.58).

The casts were placed into a laser scanner (D-250™ 3D Scanner, 3Shape A/S, Copenhagen, Denmark) (Figure



Figure 9.59. D-250 3Shape Scanner. The opaque black glass doors were open for this photograph; a cast, previously mounted with an Adesso Mounting Plate, was seated in its correct position within the scanner.

9.59). This particular company offers 3-D scanning systems that create accurate 3-D models from real objects at the push of a button. The Web site stated that all of the scanners use optical technology to capture casts' geometries precisely and are said to offer an intuitive user-friendly interface (www.3shape.com).

According to the above Web site, 3Shape's dental solutions are a unique combination of 3Shape's expertise in 3-D scanning and 3-D CAD software, which provide clinicians and dental laboratory technicians integrated solutions for the creation of accurate customized, CAD/CAM dental restorations.

3Shape's dental restoration system is completely open (output files are in a standard format) and offers advanced 3-D technology. This system allows scans of full casts, dies, or wax patterns, and designs full anatomical crowns, FPD frameworks, or implant abutments from the scanned data. 3Shape's open system allows manufacturers the possibility to manufacture products in compatible milling units and materials, as well as the benefit from the increasing number of outsourcing production centers.

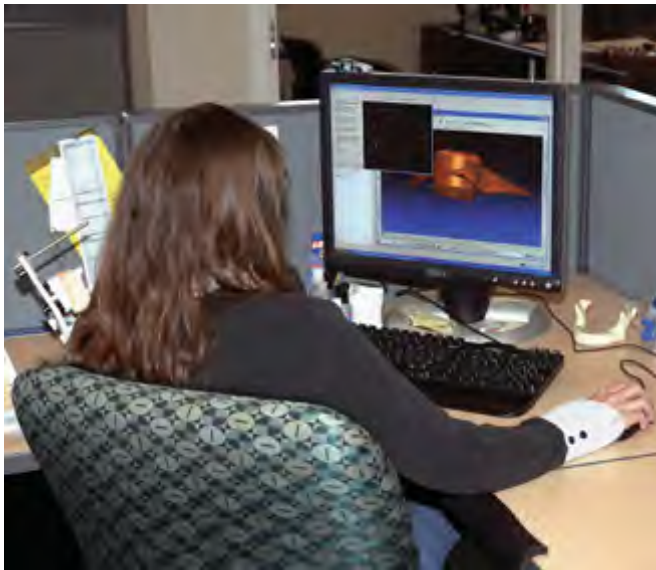


Figure 9.60. PSR designer at her computer workstation as she began to design the CAD/CAM custom abutment.

3Shape's DentalManager™ software program allows for automatic handling of all production files and transfer of the files to manufacturing equipment and/or outsourcing centers.

The casts were scanned (D-250™ 3D Scanner). The digitized data from the scanning of the Encode Healing Abutment (in die stone) were imported to the personal computer workstation of one of the PSP designers (Figure 9.60). A verification process was carried out that verified the Encode Healing Abutment as scanned represented an accurate representation of the Encode Healing Abutment in the patient's mouth (Figure 9.61). The digitized data were also sent to the robot analog placement unit in preparation for fabrication of the Robocast.

ROBOTIC PLACEMENT OF LAB ANALOG INTO CAST (ROBOCAST)

Prior to each working session, in order to ensure repeatable accuracy, the robot is put through a strenuous series of calibration exercises (Figure 9.62).

The cast was placed into the robot cast holder in preparation for the robot to remove the stone in the area of the stone Encode Healing Abutment in the master cast. A hole, specific for this restoration, was drilled into the cast (Figures 9.63–9.66). The digital data for this part of the process were obtained from the original scan of the Encode Healing Abutment in the stone cast.

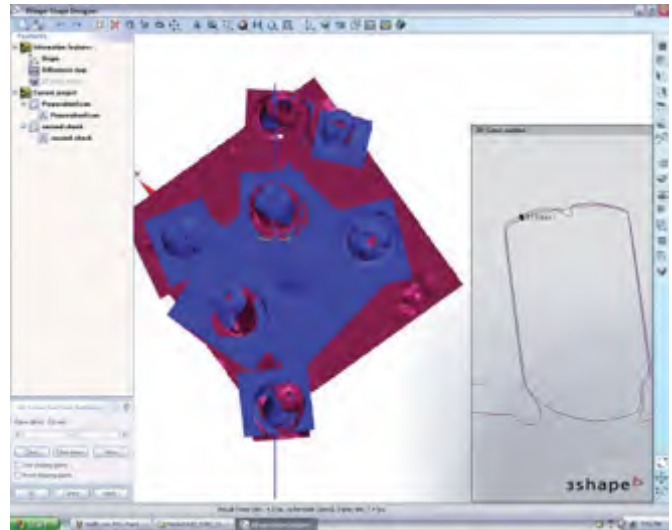


Figure 9.61. This is a computer screen image of the verification process used in the Encode Abutment protocol. The blue portion of the image was the result of the scanned Encode Healing Abutment (die stone) from a cast received at Biomet 3i. The red portion was the image from an actual Encode Healing Abutment. The cross-sectional image on the right side of the photograph indicates that the scanned image of the Encode Healing Abutment (die stone) was replicated by the scanned image of an actual Encode Healing Abutment.

A 4-mm-diameter implant analog (IILA20, Biomet 3i) was selected and placed into the analog holder (Figure 9.67). Cyanoacrylate cement was placed into the hole in the cast; a 4-mm-diameter analog was picked up by the robot and placed into the hole in the stone cast. The 4-mm-diameter analog was secured to the cast with the accelerator portion of the cyanoacrylate cement (Figure 9.68). Note that a laboratory soft tissue replica was not needed because the emergence profiles for the abutment had been previously developed in the CAD abutment design portion of the process. The Robocast process has been proven to be accurate to 0.2mm (Suttin and others 2007).

It is extremely important for the cast to be indexed and secured to the mounting plate. If a cast is not securely attached to the mounting plate, the drilling process may dislodge the cast from the mounting plate (Figure 9.69). If the cast was not indexed to the mounting plate, the process would have to be abandoned, the cast would have to be remounted on the articulator, and the scanning process would need to be repeated.

Once the cement set, this cast was called a Robocast (Figures 9.70–9.72). The unique feature of the Encode Complete Protocol is that this implant master cast with the implant lab analog in place was obtained without an



Figure 9.62. Prior to each working session, the robot must be calibrated for accuracy and reliability. These images illustrate a tactile probe of the robot touching three distinct spheres, in order to calibrate the x , y , and z coordinates required for robotic placement of implant analogs.



Figure 9.63. The digitized data identified, for the robot, the area in the cast corresponding to the maxillary right lateral incisor.



Figure 9.64. The computer directed the robot to remove the appropriate amount of stone from the area of the maxillary right lateral incisor.



Figure 9.65. The robot drilling unit completed drilling the correctly sized hole in the cast prior to placing the appropriate implant analog.

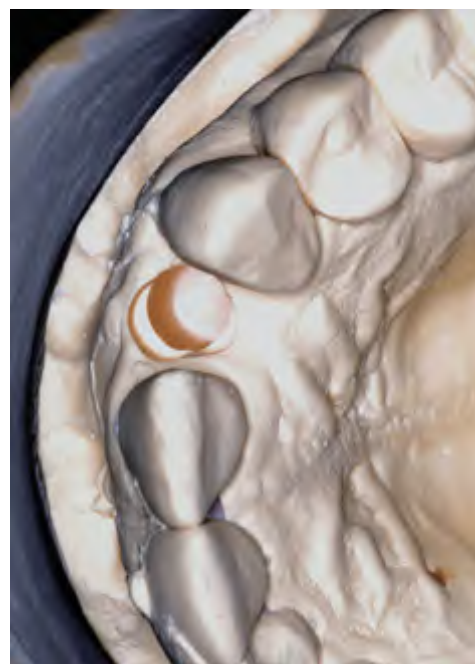


Figure 9.66. This hole was drilled by the robot in anticipation of placing a 4-mm-diameter implant analog into the cast in the area of the maxillary right lateral incisor. The orientation of the analog was dictated by identification, during the scanning process, of the occlusal codes on the occlusal surface of the Encode Healing Abutment in the master cast.



Figure 9.67. Four-millimeter internal connection implant lab analog in place in the analog holder of the robot. Package as received from the manufacturer that contained a 4-mm-diameter implant lab analog (upper left inset). Four-millimeter implant lab analog (lower left inset).



Figure 9.68. Prior to insertion of the implant analog into the cast by the robotic arm, cyanoacrylate cement was placed into the hole in the cast by the robot operator. The 4-mm implant lab analog was placed into the hole in its correct position and held in place by the robotic arm as the cement activator was applied.



Figure 9.69. During the drilling process for robotic placement of the implant analog, this cast was dislodged from the mounting plate. This cast was repositioned because it had been indexed prior to mounting.



Figure 9.70. Full-arch laboratory occlusal view of the 4-mm-diameter, internal connection implant lab analog in its correct position within the full-arch cast (Robocast).

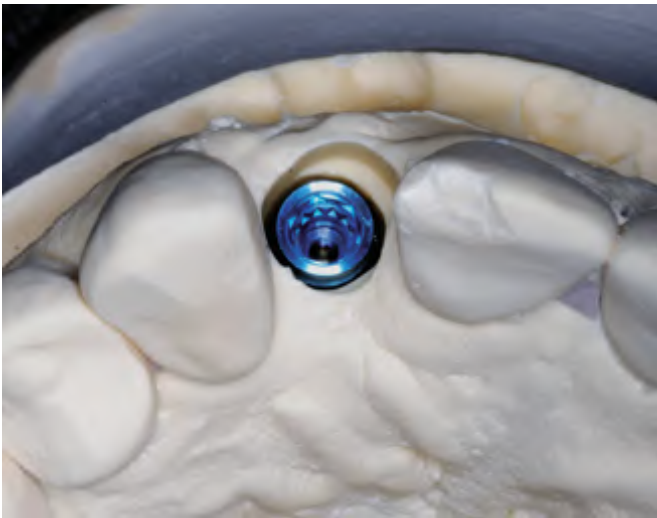


Figure 9.71. Close-up laboratory occlusal view of the 4-mm-diameter, internal connection implant lab analog in its correct position within the stone cast (Robocast). Note the absence of a soft tissue replica as the peri-implant soft tissue margins were recorded in the original scan and the abutment was designed consistent with the preoperative soft tissue contours.

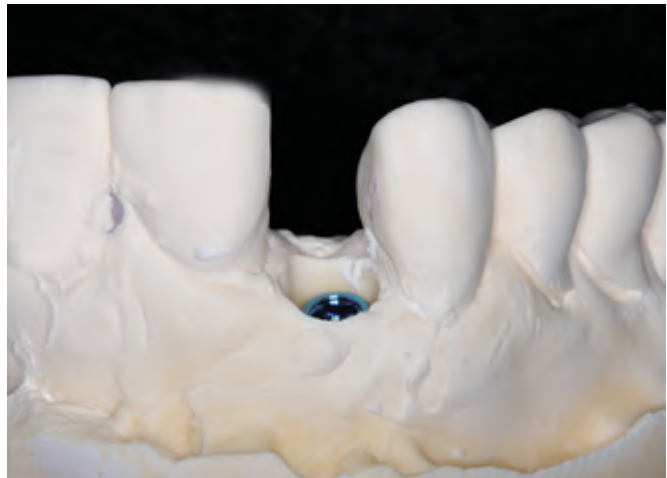


Figure 9.72. Occlusal facial laboratory view of the 4-mm-diameter, internal connection implant lab analog in place in the Robocast. There was no need for a soft tissue replica as the contours of the peri-implant soft tissues were previously taken into account during the abutment design process.

implant-level impression. The cast was sent to the shipping department, where it would be united with the patient-specific zirconia abutment prior to shipping back to the periodontist's commercial dental laboratory for fabrication of the ceramic crown.

ABUTMENT DESIGN/MILLING

The following terms will be defined per their use within the Biomet 3i PSR Department:

- SFD—shrinkage (scale) factor determination
- Green—the ceramic material state after pressing but prior to any firing/sintering operations
- Bisque (presintered)—the ceramic material state achieved after partial firing/sintering, where the material has a density less than its final achievable density
- Final density—the ceramic material state after full firing/sintering, where the material has reached its maximum achievable density

The abutment was custom designed per the instructions on the work order:

1. Margin type and location
 - a. Heavy chamfer margins
 - b. One millimeter subgingival for the facial and interproximal margins
 - c. One millimeter supragingival for the palatal margin
2. Total occlusal convergence
 - a. Approximately 6 degrees
3. Interocclusal clearance between the palatal surface of the abutment and the opposing incisal edges
 - a. Approximately 2 mm

The abutment was designed in CAD design software. If a technician wishes to view the CAD designs prior to milling, the CAD designs will be e-mailed to dental technicians for review and discussion. This discussion has to be arranged prior to designing the abutments (Figures 9.73–9.76).

The abutment design was modified to account for the shrinkage of the ceramic material during firing (SFD).

The design data were sent to the milling machine (Mikron HSM 400, Mikron Agie Charmilles, Nidau, Switzerland) for milling the ceramic abutments per the CAD designs described above (Figure 9.77). The manufacturer (milling unit) has stated that with these machines, accuracy, extreme dynamics, and high machining speeds have been combined with other important manufacturing aspects

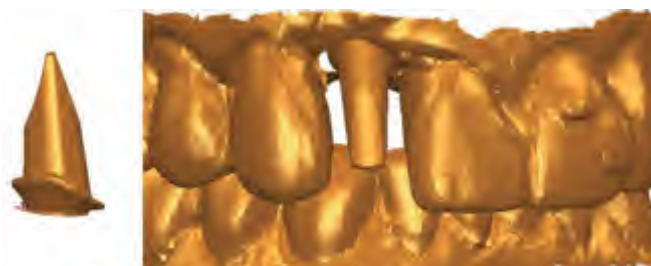


Figure 9.73. This was the first proposed abutment design as e-mailed to the dental laboratory technician for approval. The left image was a view from the mesial surface; the right image was a view with the teeth in centric occlusion. It was decided that, as designed, the facial/incisal third would not provide adequate thickness for an aesthetic all-ceramic crown. A discussion was held with the PSR technician, and a new abutment was designed.



Figure 9.74. This was the second design; it incorporated the suggestions of the ceramist from the first design. The facial/incisal third was “reprepared” in the CAD software to provide adequate space for the definitive all-ceramic crown. This view also demonstrated that there was adequate interocclusal clearance for the definitive all-ceramic crown.

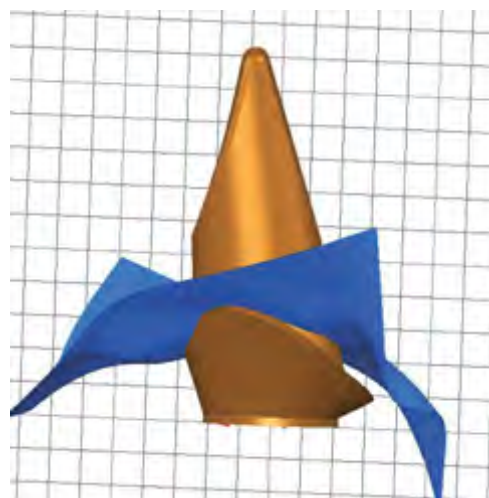


Figure 9.75. Virtual view of the mesial surface of the abutment. The adjacent tooth was removed from the image. The blue overlay represented the location of the peri-implant soft tissue. In this case, the margins were placed 1 mm subgingival.

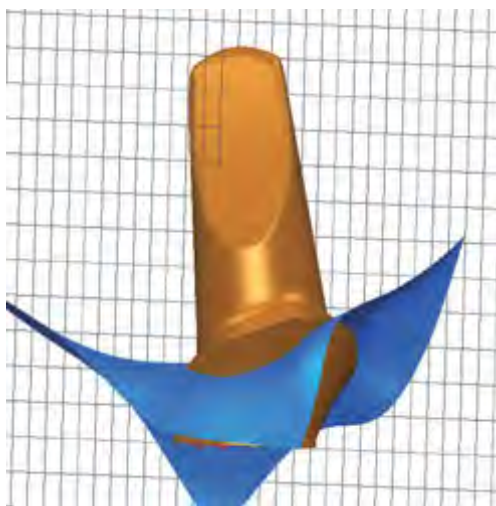


Figure 9.76. Virtual view of the palatal surface of the abutment. The adjacent teeth were removed from the image. The blue overlay represented the location of the peri-implant soft tissue. In this case, the palatal abutment margins were placed 1 mm supragingival.

such as outstanding swarf removal, high flexibility, good ergonomics, and well-integrated automation. According to the manufacturer's Web site, the unique flexibility of the HSM 400U ProdMed Dental milling unit is a key success factor by both time-to-prototype and productivity assessments. Reverse engineering has enabled dental solution providers to quickly and accurately bridge the gap between the physical and digital worlds by reading any point cloud data set, whether it is generated by a touch trigger, laser, or optical hardware system (www.gfap.com/gfac/products/high-speed-machining-centers/hsm-prodmed/mikron-hsm-400u-prodmed-dental.html?L=http%3A%2F%2Fwww.t-cross.com%2Fcgi%2Fannounce%2Fimages%2Fasawux%2Fuki%2F).

Encode Zirconia Abutments are zirconia patient-specific definitive abutments available in 3.4-, 4.1-, and 5.0-mm implant restorative platforms for the restoration of Biomet 3i's Certain implants. Zirconia custom milled abutments provide patients with improved aesthetics in two ways: first, custom milled abutments usually fit better and therefore minimize microgaps that occur between implants and abutments; second, zirconia mimics the translucency of natural teeth. The abutments are manufactured in a one-piece design; they are milled entirely from zirconia blanks. Unlike other Certain abutments, these abutments will not feature retention fingers. The abutments have a hex interface that will mate with either the 12-point double hex of the Certain MicroMiniplant™ or the six-point hex of the 4.1- and 5.0-mm Certain implants. Additionally, a screw

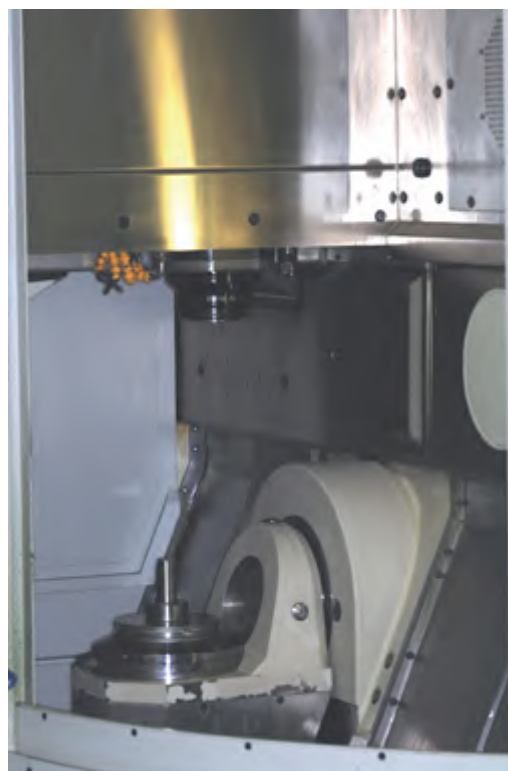


Figure 9.77. Milling unit for the Encode Zirconia Abutment.

will be used to retain the abutment to the implant following placement of the abutment.

Kollar and others (2008) studied the use of nonsilica-based high-strength full ceramics for different prosthetic indications. Fifty-two consecutive patients were followed for 12–30 months, and the most frequent cases were single crowns and short-span FPDs. They reported that overall, the periodontal parameters were favorable. Fractures of frameworks or implant abutments were not observed; abutment-screw loosening occurred once for one premolar single crown. Furthermore, five implant crowns in the posterior region exhibited chipping of the porcelain veneering material. With regard to aesthetics, no reconstructions were considered unacceptable, but three crowns were remade shortly after delivery. The authors concluded that in this short-term study, the biological, aesthetic, and mechanical properties of zirconia were favorable, and the material could be used in various prosthetic indications to restore teeth or implants.

The Encode Zirconia Abutment was recently introduced, and there are no long-term clinical trials associated with it. However, zirconia abutments have been extensively studied, and a significant number of researchers have



Figure 9.78. Laboratory view of the Encode Zirconia Abutment after milling and firing. All of the contours were milled from the agreed upon design. Facial surface (upper left); palatal surface (upper right); mesial palatal (lower left); mesial (lower right).

reported that short-term clinical results indicate that customized ceramic abutments have been successful and have comparable function with metallic abutments (Schneider and Kurtzman 2001; Henriksson and Jemt 2003; Vigolo and others 2006; Manicone and others 2007).

The final (ICZGS, Biomet 3i) and try-in (ICZTIS, Biomet 3i) screws have screw head heights of 0.090 in (relative to the abutment seating surface) so that once in place within the abutment/implant interface, the top of the screw head will be in the same vertical position as the comparable screws (IUNIHG and IUNITS, Biomet 3i) used in titanium Encode Abutments. However, the screws for this abutment are different from previous abutment screws and cannot be interchanged with other abutment screws. The catalog numbers for these screws are ICZGS and ICZTIS for the final and try-in screws, respectively.

Encode Zirconia Abutments are machined in the softer, green state and then fired. The abutments shrink with the second firing after milling; the shrinkage factor of the ceramic material is considered during the design, machining, and firing processes.

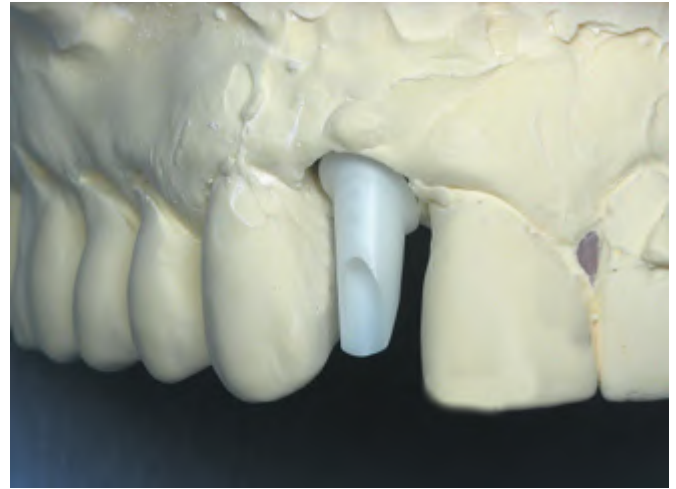


Figure 9.79. Laboratory view of the facial surface of the zirconia abutment in place on the Robocast. Note the absence of a soft tissue replica in the cast. The abutment margins were designed consistent with the location of the peri-implant soft tissues in the master cast. The stone was removed prior to analog placement. Even though the abutment margins appear to be at or just below the stone margins on the cast, the clinical facial and interproximal abutment margins are going to be 1 mm subgingival clinically.

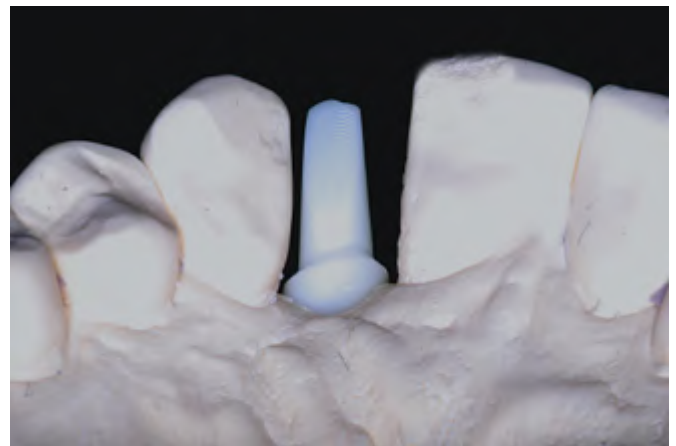


Figure 9.80. Laboratory view of the palatal surface of the abutment in place on the Robocast. Note the absence of a soft tissue replica in the cast. The abutment margins were designed consistent with the location of the peri-implant soft tissues in the master cast. The stone was removed prior to analog placement. Even though the abutment margins appear to be several millimeters above the gingival margins on the cast, the abutment's clinical palatal margin is going to be 1 mm supragingival.

The abutment was finished and polished (Figures 9.78–9.83).

The abutment and casts were wrapped, packaged, and shipped to the periodontist's commercial dental laboratory

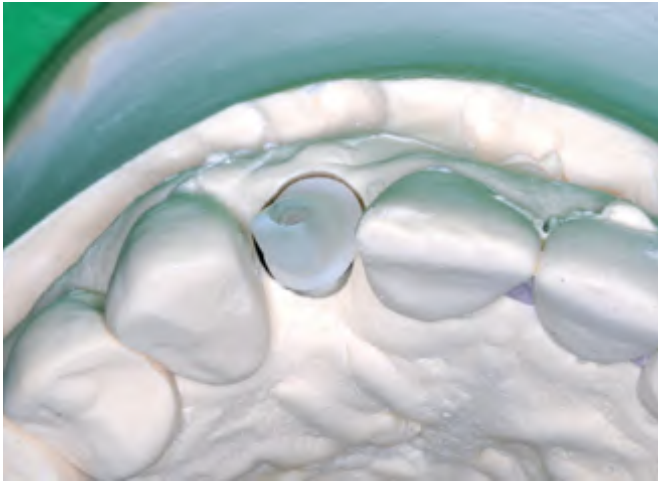


Figure 9.81. Laboratory occlusal view of the CAD/CAM zirconia abutment in place on the master cast. The axial wall in the facial/incisal third of the abutment was reduced adequately for the all-ceramic crown.

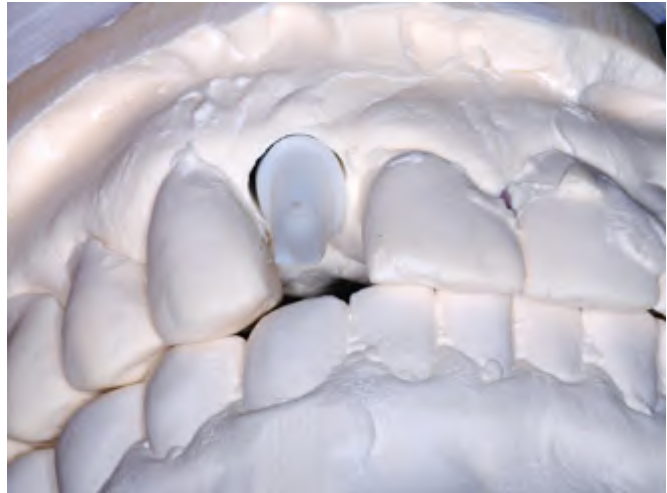


Figure 9.83. Laboratory occlusal view of the CAD/CAM zirconia abutment in place in the maxillary master cast. There was adequate interocclusal clearance in centric occlusion and all eccentric movements for the definitive all-ceramic crown.



Figure 9.82. Laboratory facial view of the mounted casts with the CAD/CAM zirconia abutment in place. The abutment was milled per the design that was agreed upon between the PSR designer and ceramist.

for fabrication of the porcelain crown (Figure 9.84). The Encode Zirconia Abutment was packaged with a try-in screw (ICZTIS) and abutment screw (ICZGS), specific for Encode Zirconia Abutments. They are not interchangeable with other try-in or abutment screws.

Encode Zirconia Abutments are relatively fragile when they are not screwed into the lab analogs. They should not be adjusted without being screwed into the analogs as a significant portion of their strength comes from the screw. If adjustments are made to the abutments without the try-in screws in place, the abutments are prone to fracture (Figures 9.85 and 9.86).



Figure 9.84. Image of the zirconia abutment shipping package, try-in screw (ICZTIS; left), Encode Zirconia Abutment (center), gold-plated abutment screw (ICZGS; right) prior to packaging for shipment to the commercial dental laboratory. In case of multiple abutments, each abutment is packaged individually and assigned an individual lot number for tracking purposes. All Encode Zirconia Abutments are shipped with try-in and abutment screws specific for Encode Zirconia Abutments.

FABRICATION OF PORCELAIN CROWN

The ceramist chose to fabricate a Nobel Procera crown due to its high strength (1200MPa) (Sierraalta and others 2003) and translucency (Sadan and others 2005).



Figure 9.85. Laboratory image of a fractured Encode Zirconia Abutment. A ceramist reportedly attempted to adjust one of the axial walls of the abutment “freehand,” not seated on the analog with a screw, and fractured the abutment.



Figure 9.86. Laboratory image of a fractured Encode Zirconia Abutment that was returned by the clinician. This clinician did not the seat the abutment completely into the implant and applied torque to the try-in screw. The abutment fractured and was returned for a new abutment. A new impression was not needed as the abutment design was digitized and saved. A new abutment could simply be remilled.

In one laboratory study, Cabrera and others (2007) investigated the failure modes and reliability of individualized Y-TZP abutments and zirconia crowns using mouth motion step-stress fatigue and the influence of manual grinding adjustments of zirconia abutments on fatigue resistance. Twenty similar Y-TZP abutments (Procera) indicated for maxillary central incisors were CAD/CAM fabricated. Ten abutments were unaltered (group-OR); 10 abutments (group-IN) received a standardized grinding adjustment (diamond burs, grit 80 μ m) to mimic in vivo preparation adaptation of the abutment collar to the marginal gingival contour. All abutments were scanned individually, and Y-TZP Procera copings were produced. Zirconia crowns (NobelRondo-veneered) were cemented conventionally (KetacCem, 3M ESPE, St. Paul, MN) on abutments screwed to Replace-Select-Tapered implants (RP 4.3 $\times$ 16mm) (Nobel Biocare). A single load to failure test was performed to estimate initial fracture resistance. Mouth motion (1.5–2Hz) step-stress accelerated fatigue testing (ELF-3300, Bose, Framingham, MA) was employed with three stress time-varying profiles. Failure was defined by abutment or screw fracture. Specimens were inspected (polarized specular reflection light microscopy) at regular intervals to visualize crack propagation and failure mode. Reliability software (Alta Pro, Reliasoft, Tucson, AZ) was employed. The preliminary results of the off-axis single load test resulted in porcelain delamination and abutment fracture (~660N). Radial crack propagation occurred in the veneering porcelain during fatigue. Ultimate failure occurred by abutment (A) or screw (S) fracture; ratio group-OR: A = 5/S = 4, group-IN: A = 3/S = 6. During fatigue, the specimens resisted maximum loads as follows: group-OR, 300–600N; group-IN, 400–575N. Weibull stress-level probability curves were calculated, and the reliability (two-sided at 90.0% confidence bounds) for 50,000 cycles and a 300-N load indicated a value of 0.73 (0.91/0.40) for all specimens ($n = 20$). Confidence bounds for the two test groups overlapped, and therefore did not demonstrate a significant difference. The authors concluded that based on their current data, implant-supported zirconia crowns and abutments exhibited appropriate fatigue resistance, even after abutment grinding adjustments.

The abutment was scanned with a Procera Forte scanning unit (Nobel Biocare), which took approximately 10 minutes (Figure 9.87). The Procera Forte scanner was purchased by this commercial dental laboratory because it added another dimension to their services by being able to scan crowns, veneers, and abutments, as well as FPDs. Its benefits and features (per the manufacturer’s Web site: www1.nobelbiocare.com/en/individualized-prosthetics/products/software-and-scanners/scanners.aspx) include the following:



Figure 9.87. The abutment was placed onto the mounting plate and was scanned with a Procera Forte scanning unit. The contours of the abutment were digitized prior to designing the zirconia coping.

- Scanning full-arch Procera Implant Bridges in titanium and zirconia
- The most precise scanner for Procera Bridge designs within a diameter of 60 × 30mm for zirconia and 70 × 30mm for titanium bridges
- Scanner precision in combination with proven production technology produces excellent marginal fit
- Short production times are directly correlated with cost-effectiveness and increased profitability
- Access to all of the existing Procera technology

Tactile scanning is known to be the most precise type of scanning available. The digitized data were manipulated with Procera software to form the desired shape for the coping. After the scanning process was completed, the design was e-mailed to Nobel Biocare, where the zirconia coping was milled. Per the manufacturer's Web site (www1.nobelbiocare.com/en/individualized-prosthetics/products/crowns.aspx), zirconia copings can be milled thinner (0.4mm in the aesthetic zone) than other competitive products currently available while maintaining exceptional strength (1200MPa). NobelProcera zirconia copings are available in four shades. The coping was returned to the ceramist for fabrication of the definitive ceramic crown (Figures 9.88–9.91).



Figure 9.88. The zirconia coping as received at the commercial dental laboratory. The coping measured 0.4mm in thickness.



Figure 9.89. Laboratory images of the zirconia coping, the zirconia abutment, and the implant lab analog.

The zirconia coping was veneered with Vita VM9[®] ceramic (Vita Zahnfabrik, Bad Sackingen, Germany). Per the manufacturer's Web site (www.inlab.com/ecomaxl/index.php?site=INLAB_Materials_ZI_VM9), Vita VM9 is the newest addition to the VM family of fine-grain porcelains. It shares VM7's desirable characteristics while satisfying the unique requirements of yttrium-stabilized zirconia

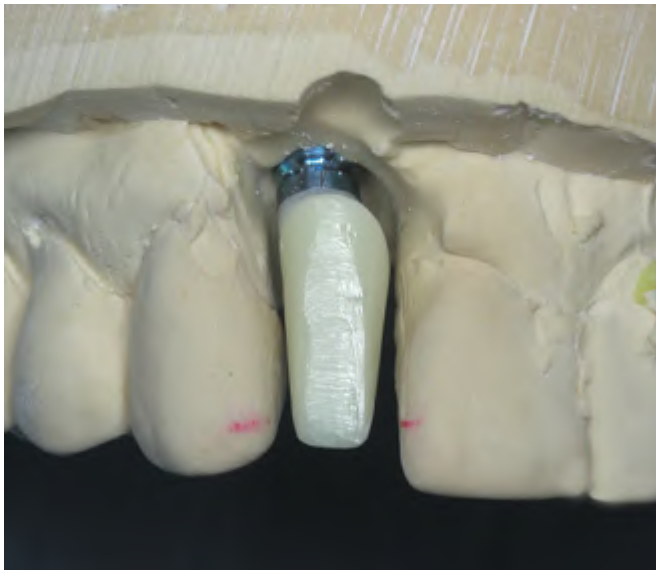


Figure 9.90. Laboratory facial view of the zirconia coping in place on the zirconia abutment in the master (Robocast) cast.



Figure 9.91. Laboratory palatal view of the zirconia coping in place on the zirconia abutment in the master (Robocast) cast.

(coefficient of thermal expansion [CTE] of 10.5) and has been specifically designed for Vita YZ Cubes.

Vita VM9 Build Up layering ceramic consists of base dentin, dentin, and enamel. The use of the three-layer method permits reduced and more individual application of the enamel porcelains, and can result in a more convinc-



Figure 9.92. Laboratory facial view of the ceramic crown in place on the zirconia abutment in the Robocast.



Figure 9.93. Laboratory palatal view of the ceramic crown in place on the zirconia abutment in the Robocast.

ing reproduction of natural teeth. By combining enamel and dentin according to the layer thickness of base dentin, the intensity of the shade can be individualized. An increased proportion of base dentin results in an intensified shade; larger quantities of dentin and enamel reduce the chroma of the shade (Figures 9.92 and 9.93). This crown was fabricated with light centric occlusal contacts. The crown, abutment, and implant were not involved with lateral or protrusive excursions.

An abutment placement index was fabricated on the Robocast with autopolymerizing acrylic resin. This index transferred the precise position of the abutment on the implant lab analog by identifying the positions of the incisal edges of the adjacent teeth (Figure 9.94). The index was made with the try-in screw and 0.048-in driver (PHD03N,



Figure 9.94. Laboratory facial view of the abutment placement index in place on the Robocast. The resin index was made with the abutment in its correct position. The index was keyed to the incisal edges of the adjacent teeth; it was made with the driver in place (inset). This maintained the integrity of the screw access opening. The entire complex (index, abutment and try-in screw) could be easily and accurately transferred from the cast to the mouth. Abutment placement indexes have proved to be beneficial for clinicians with limited experience in implant restorative dentistry.

Biomet 3i) in place. It is extremely important to note that Encode Abutments require the use of the narrow drivers and driver tips. The regular drivers (PHD02, PHD03, Biomet 3i) have shaft diameters that are too large for the screw access openings of Encode Abutments. If technicians or clinicians attempt to use the regular drivers with Encode Zirconia Abutments, the abutments will fracture. Autopolymerizing acrylic resin was mixed and placed onto the abutment. The driver maintained the integrity of the screw access opening. After this material set, a light-cured resin material was placed onto the incisal edges of the adjacent teeth and onto the acrylic resin coping on the abutment; care was taken to keep the material superior, and out of the undercuts of the teeth. The material was cured; the index was removed from the cast with the abutment in place (Figure 9.95). The driver was removed, and now the periodontist had an index that would enable him to place the zirconia abutment into its correct position with the six-point internal hex of the implant.

The casts, abutment, and crown were carefully packaged and shipped to the periodontist's office for insertion.

CLINICAL INSERTION

The patient returned for the clinical insertion appointment; he reported no problems since the last visit and was anxious to proceed with the clinical procedures (Figures 9.96 and 9.97).



Figure 9.95. Laboratory intaglio view of the abutment placement index with the abutment attached. The indentations of the incisal edges are visible in the index. These indentations were intended for the clinician to easily transfer the location of the abutment's hex from the laboratory Robocast to the intraoral implant by using the visible incisal edges of the adjacent teeth as landmarks.



Figure 9.96. Clinical facial image of the Encode Healing Abutment on the day the patient presented for insertion of the definitive zirconia abutment and ceramic crown. This abutment has been in place since the implant was placed. Note the excellent peri-implant soft tissue response and adaptation to the healing abutment.

The healing abutment was removed with the appropriate driver (PHD03N). The peri-implant soft tissues had healed consistent with the size and shape of the healing abutment (Figure 9.98).

The abutment, with the try-in screw (ICZTIS), was placed into the abutment placement index; the indentations in the occlusal portion of the index were aligned with the incisal



Figure 9.97. Clinical occlusal image of the Encode Healing Abutment on the day the patient presented for insertion of the definitive zirconia abutment and ceramic crown. The occlusal codes of the abutment were still supragingival, the abutment was highly polished and appeared to be plaque free. The healing abutment was removed with the 0.048-in driver (PHD03N; inset).



Figure 9.98. Clinical occlusal image of the implant restorative platform after the healing abutment was removed. The peri-implant soft tissues had healed consistent with the size and shape of the healing abutment. The entire implant restorative platform was visible.

edges of the adjacent teeth, and the entire complex went to place intraorally. Clinicians must make sure that the abutment is completely seated into the implant prior to applying any torque to the driver as the abutments are weak and prone to fracture without being stabilized by the try-in screw.

The try-in screw was hand tightened, and a radiograph was taken (Figure 9.99). It is extremely important for clinicians to make sure that these abutments are completely

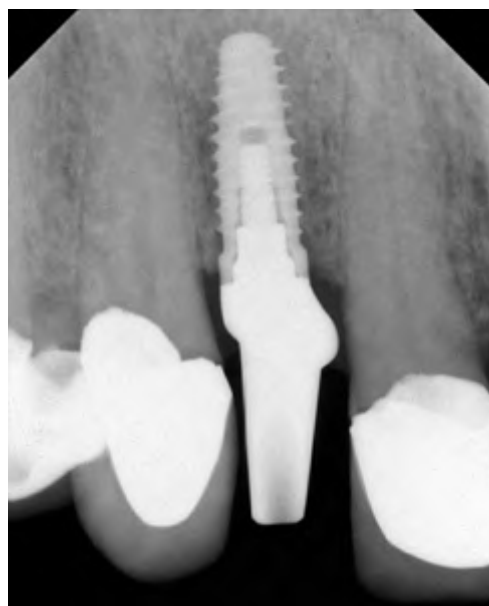


Figure 9.99. Verification radiograph with the zirconia abutment and try-in screw in place. The abutment was correctly seated into the implant prior to placing any torque on the try-in screw.



Figure 9.100. Labial view of the zirconia abutment in place. The facial and interproximal margins were located approximately 1 mm subgingival. Try-in screw (ICZTIS; upper left inset).

seated into the implant hex and that the driver is parallel to the long axis of the abutment prior to exerting any turning pressures to the driver, as these abutment are relatively weak under tension without the abutment screws properly seated. The abutment was judged to be accurately and completely seated (Figures 9.100 and 9.101).

The ceramic crown was taken to the mouth and tried onto the abutment. The interproximal contacts were adjusted as



Figure 9.101. Palatal view of the zirconia abutment in place. Note that the palatal margins were located slightly supragingival, as designed.



Figure 9.103. Palatal view of the crown in place.



Figure 9.102. Labial view of the crown in place. The clinical crown was rectangular in shape. It lacked the triangular appearance associated with a normal maxillary lateral incisor. In hindsight, the implant should have been 3.25 mm in diameter, with a 3.4-mm restorative platform. By reducing the platform size, the gingival contours of the crown would have been narrower than the middle and incisal thirds of the crown. This would have resulted in a more tapered, aesthetic crown restoration.



Figure 9.104. Periapical radiograph of the zirconia abutment and ceramic crown in place. The crown was completely seated onto the zirconia abutment.

needed to obtain complete seating of the crown onto the abutment (Figures 9.102 and 9.103). Another radiograph was taken that verified the crown was completely seated onto the abutment (Figure 9.104).

The occlusion was evaluated with the patient seated upright and reclined; it was adjusted so that the mandibular posterior buccal cusps were in contact with the opposing central fossae of the maxillary posterior teeth. Right working disclusion was obtained with the maxillary and

mandibular cuspid teeth. There were no balancing side contacts when the patient went into working movements. Anterior guidance was a function of the central incisors.

The crown and abutment were removed from the implant, and the crown was polished. The abutment was placed back into the abutment placement index in its correct position and was resealed onto the implant via the indentations that corresponded to the incisal edges of the adjacent teeth. The definitive abutment screw (ICZGS, Biomet 3i)



Figure 9.105. Diagrammatic illustration of the proper method to seat the zirconia abutment: place the abutment completely into the implant hex, seat the driver (PHD03N) into the abutment screw (ICZGS), and then hand tighten the screw (left to right).



Figure 9.106. This is the Contra Angle Torque Driver Kit as sold by Biomet 3i. It contains a contra-angle torque driver body; 20 and 32Ncm torque controllers; two hand drivers; and four contra-angle driver tips. RASH3N contra-angle driver tip (right inset).

was hand tightened with the large hex driver (PHD03N) (Figure 9.105). The large hex driver tip (RASH3N, Biomet 3i) was placed into the torque driver (CATDB, Biomet 3i) and placed through the abutment screw access opening into the head of the abutment screw inside of the implant. This screw was torqued to 20Ncm with the use of a torque controller calibrated to deliver 20Ncm of torque (Figure 9.106). The screw access opening was blocked out with



Figure 9.107. Clinical labial image of light-cured composite resin being polymerized intraorally. A cotton pellet was placed over the screw head prior to placing composite resin into the screw access opening.



Figure 9.108. Clinical labial image of the patient post cementation of the ceramic crown in the maxillary right lateral incisor site.

cotton and a light-cured resin restoration was placed to seal the screw access opening (Figure 9.107). The crown was cemented to the abutment with dual-cure cement. The excess cement was removed, and the patient was discharged (Figures 9.108 and 9.109).

The treatment described in this chapter illustrated the use of new technologies in replacing a missing maxillary lateral incisor tooth with a cement-retained, ceramic crown restoration on a CAD/CAM zirconia abutment without an implant-level impression. It featured a CAD/CAM technology that designed and milled a patient-specific zirconia abutment and all-ceramic crown. This protocol has numerous benefits for clinicians and dental laboratory technicians, including allowing laboratories to fabricate state-of-the-art CAD/CAM abutments without purchasing expensive scanners and milling units. Restorations constructed in this manner are relatively simple to fabricate and provide excellent aesthetics and function. Labor costs are



Figure 9.109. Clinical image of the patient speaking. The gingival margin of the implant restoration is not visible during lip movements. The shade of the ceramic restoration blends in nicely with the other anterior teeth.

decreased as well. Dental laboratories can increase their implant business, and therefore profitability, by increasing the number of general dentists who can now be involved in implant restorations, as well as providing high-quality patient-specific CAD/CAM abutments for their experienced restorative dentists.

The following clinicians and dental laboratory technicians were responsible for the treatments illustrated in this chapter:

Periodontist: C. Garry O'Connor, DDS, MS; La Crosse, WI

Restorative Dentist: James Allen, DDS; West Salem, WI

PSR Designer: Nancy Cronin, Palm Beach Gardens, FL.

Dental Laboratory Technicians: The abutment was slightly re-milled by Mr. Anatoliy Shakarov; the diagnostic wax pattern was made by Mr. Alexey Zorin; the abutment was scanned by Mark Power; the zirconia coping was veneered by Tom Bruner, CDT, North Shore Dental Laboratories, Lynn, MA

Illustrator: Robin deSomer Pierce, BSMI, Palm Beach Gardens, FL

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Chapter 10: Computed Tomography (CT)-Guided Surgery/ Immediate Occlusal Loading with a Full-Arch Prosthesis in Edentulous Maxillae

INTRODUCTION

It is well known that the jaws of edentulous patients undergo significant, irreversible resorptive changes after loss of the natural teeth (Atwood and Coy 1971; Tallgren 1972). These resorptive processes cause significant changes in the anatomy of the edentulous jaws, which may lead to problems with patients adapting to complete dentures. Long-term bone resorption can, in some instances, preclude implant placement (Gelb 1993). In those cases, bone grafting procedures may or may not be successful in providing enough bone for implant placement. For optimal restoration of function and aesthetics in edentulous patients with anatomic limitations, additional surgeries and technically demanding prosthetic procedures may be required. These additional procedures increase morbidity and may result in decreased overall success rates for implant treatment. Treatment times and costs will also be increased.

Initially, loading dental implants were governed by a strict protocol (Brånemark and others 1977; Albrektsson and others 1986). Immediate loading of dental implants in the 1960s resulted in fibrous encapsulation of the implants, implant mobility, and loss of implants (Linkow and Charchee 1970). Clinical research on dental implants increased, and it was found that under certain circumstances, immediate occlusal loading of endosseous implants could be as efficacious as the unloaded healing protocol described above. Schnitman and others (1990, 1997) reported on immediate fixed interim prostheses supported by Brånemark implants in the treatment of mandibular edentulism. These researchers reported that the 10-year cumulative survival rate (CSR) for all of the implants placed (immediate occlusal loading and nonloaded healing protocols) at 93.4%. Life table analysis of the immediately loaded implants demonstrated a 10-year CSR of 84.7%. The 10-year CSR for the nonloaded implants was 100%. These two sets of data were statistically significant ($P = 0.022$).

Tarnow and others (1997) reported on immediate occlusal loading in edentulous maxillae and mandibles with both machined and altered implant surfaces. Edentulous maxillae are remarkably different from edentulous mandibles on both macroscopic and microscopic levels. Maxillary bone has a lower density than mandibular bone between the

mental foramen (Brånemark and others 1977; Albrektsson and others 1986). Trabecular bone, which occurs in higher amounts in edentulous maxillae, is softer than cortical bone and is therefore more difficult to achieve high implant stability at implant placement, which many consider to be the most important factor in the osseointegration process (Friberg and others 1991). In soft bone, undersizing the osteotomies and selecting implants of differing shapes, lengths, and diameters may help overcome anatomical limitations and permit the attainment of a high primary stability (Adrianssens and Herman 2001). Insertion torque of at least 40Ncm has been suggested as the minimum value acceptable for immediate implant loading (Vanden Bogaerde and others 2003), although there is some debate on this subject as it pertains to multiple, splinted implants versus single, unsplinted implants (Del Fabbro and others 2006). Brunski (1993) has hypothesized that micromovement of implants within their osteotomies can have a negative impact on osseointegration. Others have suggested that precise surgical and prosthetic protocols have to be followed for predictable osseointegration (Skalak 1983; Galli and others 2008; Testori and others 2008).

Tealdo and others (2008) recently published a study that evaluated the 12-month implant survival after immediate loading of four to six implants with fixed screw-retained prostheses in edentulous maxillae. They identified this protocol as the Columbus Bridge Protocol. Twenty-one patients, edentulous or with remaining teeth to be extracted in maxillae, received four to six implants ($n = 111$). All patients were restored with screw-retained fixed provisional prostheses supported by palladium alloy frameworks within 24 hours after surgery. Insertion torques for implants were at least 40Ncm. Implants, grouped as tapered or cylindrical screws, were placed into healed bone or immediate extraction sockets. Implants were also classified as either vertical or off-angle. Definitive prostheses were placed after a mean healing time of 18 weeks. Radiographic examinations were made at the time of placement of provisional prostheses and 12 months later. Between groups, the bone resorption was compared using two-way analysis of variance (ANOVA) ($\alpha = 0.05$). The mean follow-up time for all of the patients was 20 months (range: 13–28 months). The cumulative implant survival rate at the 12-month follow-up visits (after surgery) was 92.8%; the prostheses survival rate was 100%. No

significant differences were found between the survival of tapered or cylindrical screw-type implants placed into postextraction sockets versus those in healed edentulous sites or between vertical and off-angle placed implants. Eight implants failed during the first 3 months, five of which were the most distal implants. The mean reduction in marginal bone height over the 12-month observation period was 0.84 mm (95% confidence interval [CI]; 0.68–0.99 mm). Tealdo and others (2008) concluded that at the 12-month follow-up period in their study, four to six implants were sufficient to successfully support fixed implant screw-retained prostheses in the edentulous maxillae of 21 patients.

TILTED IMPLANTS

The presence of the maxillary sinus may limit or preclude implant treatment in posterior maxillae. Tilting of distal implants supporting fixed restorations has been proposed by several researchers and may be a valid treatment alternative to bone grafting posterior maxillary quadrants (Bergkvist and others 2005; Maló and others 2005; Tealdo and others 2008). Zampelis and others (2007) evaluated the concept of tilting splinted implants regarding stress distribution in the bone surrounding implant restorative platforms and also compared the use of tilted implants as distal abutments with vertical implants and the use of distal cantilevers. They constructed a two-dimensional (2-D) model for finite element analysis using two 13-mm implants splinted by a titanium beam, 16 × 3 mm. The implants were embedded in bone blocks, simulating different bone properties. A small crater was created in the marginal bone around the tilted implant to simulate physiological bone remodeling. The model with a 7-mm-long distal cantilever and a vertical distal implant was compared with a model in which the distal implant (13 or 19 mm) was tilted distally 45 degrees and supported the distal end of the cantilever. A force of 50 N was applied via the beam. They reported that the stress at the most coronal bone-to-implant contact was identical irrespective of the angle of tilt and demonstrated that tilting splinted implants does not result in increased stress to the bone at the implant restorative platform. The cantilevered model showed that the use of cantilevers resulted in higher stress in the marginal bone around implants. This stress was reduced to “normal” levels when the cantilever arm was negated by the distal implant being apically inclined to support the distal end of the cantilever. The use of a longer implant only minimally reduced the stress. Zampelis and others (2007) concluded that within the limitations of this 2-D finite element analysis, it appeared that distal tilting of implants splinted by fixed restorations did not increase bone stress compared with vertical implants. There was a biomechanical advantage in using tilted distal implants rather than distal cantilevers.

Capelli and others (2007) reported on the results of a study that assessed treatment outcomes of immediately loaded full-arch screw-retained prostheses with distal extensions supported by both upright and tilted implants for the rehabilitation of edentulous jaws. At four clinical centers, 342 implants (Osseotite NT®, Biomet 3i, Palm Beach Gardens, FL) were consecutively placed into 65 patients (96 implants/24 mandibles; 246 implants/41 maxillae). The two distal implants in each jaw were tilted 25–35 degrees. Provisional full-arch restorations (titanium frameworks and acrylic resin teeth) were delivered within 48 hours of surgery and immediately loaded with full functional occlusions. The definitive prostheses were delivered 3 months post implant and prosthesis placement.

Capelli and others (2007) reported that three implants failed during the first year and another two implants failed within 18 months of loading in maxillae. The CSR for the maxillary implants was 97.59%, with up to 40 months of follow-up. No implant failures were recorded in the mandibles. The prosthetic survival rate for both jaws was 100%. For this time period, marginal bone loss around the upright and tilted implants was similar. Patients reported that they were satisfied with their aesthetics, phonetics, and function. Capelli and others (2007) concluded that the preliminary results suggested that immediate occlusal loading of edentulous maxillae and mandibles with hybrid prostheses supported by six or four implants, respectively, may represent a viable treatment alternative for treating edentulous patients without significantly more invasive surgeries such as sinus lifts or block bone grafts. At least for the course of this study, the clinical results indicated that immediately loaded tilted implants achieved the same outcome as upright implants in both jaws. Other researchers have reported similar high CSRs for immediate occlusal loading in both edentulous jaws (Bergkvist and others 2005; Maló and others 2005; Tealdo and others 2008).

Agliardi and others (2008) performed a prospective study to evaluate a new surgical approach for the immediate rehabilitation of edentulous maxillae without any type of bone grafting. They named this protocol “V-II-V.” It consisted of an immediately loaded full-arch provisional prosthesis supported by six implants: two distal implants engaged the posterior walls of the maxillary sinus (tilted 30–45 degrees relative to the occlusal plane); two other tilted implants engaged the anterior walls of the sinus; and two axial implants were inserted into the anterior maxillae. An acrylic resin provisional restoration was delivered within 4 hours of implant placement. At each follow-up visit, plaque and bleeding indexes were scored, marginal bone level changes around tilted and axial implants were evaluated, and a questionnaire was compiled to assess patient's satisfaction for function and aesthetics. Twenty-one patients were treated in this study. A total of 126

implants were placed. Nineteen prostheses were in function for more than 12 months. The average follow-up time period was 20 months (range: 4–35 months). No implant failures occurred up to the time of publication. The CSR was 100% for both implants and prostheses. They reported no surgical or prosthetic complications. The peri-implant bone loss at the axial and tilted implants was similar at 1 year: 0.8mm (SD = 0.4, $n = 28$) and 0.9mm (SD = 0.5mm, $n = 56$), respectively ($P > 0.05$). Agliardi and others (2008) concluded that the “V-II-V” technique was a viable treatment modality for the immediate rehabilitation of edentulous maxillae. They cautioned that long-term evaluation was needed to confirm these encouraging preliminary results.

COMPUTED TOMOGRAPHY (CT)

CT is a digital imaging modality that creates tomographic sections where the layers are not blurred with artifacts from adjacent anatomical structures. CT allows differentiation between the hard and soft tissues, thus allowing accurate images of teeth, lamina dura, periodontal ligament spaces, cortical bone, and alveolar bone. CT produces axial images perpendicular to the long axis of the anatomy being examined. CT images are, by definition, three-dimensional (3-D) images, with thicknesses corresponding to the slice spacing of the particular imaging protocol. Each individual element of a CT image is called a voxel and has a value (Hounsfield units) that describes the density of the CT image. Each voxel contains 12 bits of data and ranges from –1000 (air) to +3000 (enamel/dental materials) Hounsfield units. CT scanners are generally calibrated at a Hounsfield value of 0 for water. The CT density scale is quantitative and meaningful in identifying and differentiating structures and tissues.

The efficacy of CT for imaging the maxillofacial regions has been documented since its introduction in the 1980s (Helms and others 1982). The differences in tissue densities can be used to differentiate tissues within each image and can also characterize bone quality according to Lekholm and Zarb (1985), Shahlaie and others (2003), and Lee and others (2007).

Ganz (2008) published a paper regarding CT and cone beam CT (CBCT) technology and stated that these modalities provided clinicians with new methods to view patient anatomy exceeding conventional 2-D radiology. Ganz (2008) wrote that interactive software applications allowed for improved interpretation of CT scan data. Ganz (2008) also cautioned that proper use of this new technology must be based on a solid foundation of fundamental surgical and prosthodontic protocols. Advances in software and associated hardware have empowered clinicians with the necessary tools to harness the technology while remaining

true to conventional standards. The enhanced capability of innovative software applications allows clinicians to interpret and maneuver through various 3-D images. This will have far-reaching implications when interactive treatment planning software is combined with computer-aided design and manufacturing. Ganz (2008) stated that using all available virtual tools, true restorative-driven implant dentistry can be accomplished, ultimately benefiting patients with more predictable implant placement and prosthetic designs.

The improved diagnostic capabilities of CT, especially in regard to treatment planning for dental implants, has been well known for quite some time (Eckerdal and Kvint 1986; Stella and Tharanon 1990). However, access to CT scanners by dentists was limited, as was the interpretation of the scans by radiologists. The logistics of reformatting CT scans was laborious, and then the information was shipped to the referring dental practitioner for use, who may or may not have known how to interpret the studies. These difficulties led to the development of CT scanning for dental purposes. The new scans were identified as Dentascans (Kircos and Misch 2005).

Kircos and Misch (2005) identified the limitations of Dentascans:

1. Images may not be true size and require compensation for magnification
2. Determination of bone quality required the use of the imaging computer
3. Hard copy Dentascan images included only a limited range of the diagnostic gray scale of the study
4. The tilt of the patient's head during the examination was critical to maintain since the cross-sectional images must be perpendicular to the axial imaging plane

CBCT

Cone beam imaging has gained broad acceptance in dentistry in the past 5 years (White 2008). White (2008) reviewed the use of CBCT imaging in dentistry and considered issues requiring further development. Cone beam machines emit an X-ray beam shaped like a cone rather than a fan as in conventional CT machines. After this beam passes through the patient, the remnant beam is captured on an amorphous silicon flat panel or image intensifier/charge-coupled device (CCD) detector. The beam diameter ranges from 4 to 30 cm and exposes the head in one pass around the patient, capturing from 160 to 599 basis images. These images, measured in voxels, are used to compute a volume from which planar or curved reconstructions can be extracted in any orientation. Voxels are isotropic and can be as small as 0.125mm. Three-dimensional images of

bone or soft tissue can also be generated. The most common indications for cone beam imaging in dentistry are assessment of the jaws for placement of dental implants, evaluation of the temporomandibular joints for osseous degenerative changes, examination of teeth and facial structures for orthodontic treatment planning, evaluation of the proximity of mandibular third molars to the inferior alveolar canal prior to extraction, and evaluation of teeth and bone for signs of infections, cysts, or tumors. In White's (2008) opinion, cone beam images have largely replaced conventional tomography for these tasks. The effective dose from cone beam imaging ranges from 6 to 477 microSv. White (2008) proposed that the issues to be considered in the future are the training of individuals making and interpreting cone beam images, as well as means to further reduce patient exposure.

Compared with conventional radiography, CT technology requires substantially more financial investment and effort (computerized tomographic imaging, fabrication of scanning appliances, intraoperative referencing for bur tracking, and/or image-guided manufacturing of surgical templates) but appears superior on account of its potential to eliminate possible manual implant placement errors and systematize reproducible treatment success. The potential for the protection and avoidance of critical anatomical structures and the aesthetic and functional advantages of prosthodontic-driven implant positioning must also be considered. However, long-term clinical studies are necessary to confirm the value of this strategy and to justify the additional radiation dose, effort, and costs (Widmann and Bale 2006).

INTERACTIVE CT

Interactive CT has addressed many of the limitations associated with CT (Van Steenberghe 2005). The digital scanning information can now be transferred to a disk from the imaging center. With the appropriate software program, clinicians can now develop treatment plans on their personal computers. Per Parel and Triplett (2004), interactive CT allowed for precise treatment planning regarding implant positions; the images may also be used for construction of surgical guides and definitive prosthetic fabrication prior to surgery. They found that this technology was powerful, easy to use, and concluded that it would give clinicians significant advantages in implant dentistry.

Van Assche and others (2007) reported on the precision of the transfer of computer-based 3-D treatment planning, using reformatted cone beam images, for oral implant placement in partially edentulous jaws. They imaged four formalin-fixed cadaver jaws in 3-D Accuitomo FPD (J. Morita Mfg. Corp., Kyoto, Japan) CBCT. Data were used to treatment plan dental implant placement in the partially

edentulous jaws and then transferred the data to surgery with stereolithographic (SLA) drill guides. Preoperative CBCT images were subsequently matched with postoperative CT images, and the deviations between the planned implant locations and the locations of the actual implants were calculated. They reported that the actual implant positions (length: 10–15 mm) showed an average angular deviation of 2 degrees (SD = 0.8, range: 0.7–4.0 degrees) as compared with the treatment planned images. The mean linear deviation was 1.1 mm (SD = 0.7 mm, range: 0.3–2.3 mm) at the implant restorative platforms and 2.0 mm (SD = 0.7 mm, range: 0.7–2.4 mm) at the implant apices. Van Assche and others (2007) concluded that CBCT images could be used for implant treatment planning, but clinicians needed to be aware that, according to their results, there could be a maximum 4 degrees angulation error and 2.4 mm linear deviation at the implant apices from the preoperative, planned implant positions.

ACCURACY IN CT TREATMENT PLANNING

Veyre-Goulet and others (2008) wanted to assess and quantify the accuracy of linear measurements provided by CBCT using an image intensifier tube and television chain as an X-ray detector, despite a loss of contrast resolution. It is well known that information on bone width is lacking in conventional radiography and that bone height may be incorrect as well because of distortion caused by positioning errors and variable magnification (Petrikowski and others 1989; Bou Serhal and others 2002).

Veyre-Goulet and others (2008) drilled three holes into posterior maxillae of three dry human skulls and filled the holes with gutta percha. CBCT scans were taken, and the measurements were then compared between the scanned data points and the actual dry skull measurements. Veyre-Goulet and others (2008) reported, in the dry skull specimens, differences between the two data sets of between 0.05 and 0.3 mm and concluded that CBCT images provided reliable information on bone quality for preoperative implant planning in the posterior maxillae.

Around the year 2000, rapid prototype medical modeling and the use of SLA surgical guides manufactured from CT scans became available to the dental profession (Klein and Abrams 2001; Tardieu and others 2003).

Ozan and others (2009) reported the results of a clinical study to determine the angular and linear deviations at the implant restorative platforms and apices between CT treatment planned and actually placed implants using SLA surgical guides. All patients wore radiopaque scanning appliances, made from diagnostic patterns or casts, during CT scanning. Treatment plans were developed, and the data were sent for fabrication of SLA surgical guides using

a rapid prototype method with a laser beam. They placed 110 implants using the SLA surgical guides generated from CT scans. After implant placement, new CT scans were made for each patient. Special software was used to match images of the planned and placed implants, and their positions and axes were compared. The mean angular deviation of all placed implants from the planned placements was 4.1 ± 2.3 degrees; the mean linear deviation was 1.11 ± 0.7 mm at the implant restorative platform, and 1.41 ± 0.9 mm at the implant apices. The angular deviations of the placed implants compared with the planned implants were 2.91 ± 1.3 degrees, 4.63 ± 2.6 degrees, and 4.51 ± 2.1 degrees for the tooth-supported, bone-supported, and mucosa-supported SLA surgical guides, respectively. Ozan and others (2009) concluded that the results of the study suggested that SLA guides using CT data may be reliable in implant placement, and tooth-supported SLA surgical guides were more accurate than bone- or mucosa-supported SLA surgical guides.

In a similar study, Ersoy and others (2008) reported on the results of 92 implants and found that compared with where the implants were planned, the placed implants showed angular deviations of 4.9 ± 2.36 degrees. The overall mean linear deviation was 1.22 ± 0.85 mm at the implant restorative platforms and 1.51 ± 1 mm at the implant apices. Compared with the planned implant placement, the angular deviation and linear deviation at the implant restorative platforms and apices of the placed maxillary implants were 5.31 ± 0.36 degrees, 1.04 ± 0.56 mm, and 1.57 ± 0.97 mm, respectively, whereas corresponding figures for the placed mandibular implants were 4.44 ± 0.31 degrees, 1.42 ± 1.05 mm, and 1.44 ± 1.03 mm, respectively. Ersoy and others (2008) also concluded that SLA surgical guides using CT data may be reliable in implant placement.

PREOPERATIVE PLANNING

Treatment planning includes selection of the appropriate implant lengths, diameters, and 3-D locations. The number of implants planned to support an implant prosthesis is one of the fundamental elements to long-term success in implant dentistry. Before implants are placed, the anatomical foundation must be assessed.

During presurgical restorative treatment planning for patients who may receive immediate provisional prostheses, it is important for the surgeon, restorative dentist, and dental laboratory technician to have input into the proposed design(s) of the provisional prosthesis and the type of restorative components that will be used. This type of decision making is critical for determining the optimal location of the implants. With CT-guided treatment planning, this can be accomplished accurately prior to the surgical appointment. A treatment planning approach that starts

with the design of the provisional prosthesis and is followed by implant location and abutment selection is preferred by the authors.

Clinical information necessary for treatment planning includes, but is not limited to, determining the appropriate vertical dimension of occlusion (VDO), evaluating the amount of interocclusal distance available from the crest of the edentulous ridge to the opposing dentition (occlusal plane), identifying the locations of important anatomic structures, and determining the bone dimensions in the three planes of space, especially relative to the planned locations of the teeth. Therefore, the implant team should evaluate all of these dimensions in planning the implant restorative components to be used.

Diagnostic casts should be used preoperatively, and in the case of edentulous jaws, should also be mounted on an articulator. In some case, diagnostic wax dentures will be needed to locate tooth positions prior to fabrication of the scanning appliance. Surgical guides have proven helpful in assisting surgeons with the planned locations of the teeth in the prosthesis.

CLINICAL PATIENT PRESENTATION

A 58-year-old male presented to the periodontist (Dr. del Castillo) with a chief complaint, "I don't like my upper denture, and I want implants. I don't want a denture to come out."

The teeth had been missing for at least 10 years (Figure 10.1). The periodontist had grafted the maxillary sinuses approximately 12 months previously (Figures 10.2 and 10.3). The patient was not happy with how the maxillary denture felt and complained that he missed "feeling" his food during eating. He did not like that his palate was



Figure 10.1. This patient's original preoperative panoramic radiograph demonstrated significant pneumatization of the right and left maxillary sinuses.



Figure 10.2. Surgical intraoperative photograph of the closed incision in the right posterior maxilla immediately after sinus grafting.



Figure 10.3. Surgical intraoperative photograph of the closed incision in the left posterior maxilla immediately after sinus grafting.



Figure 10.4. Clinical image of the patient with the existing maxillary denture in place at rest.

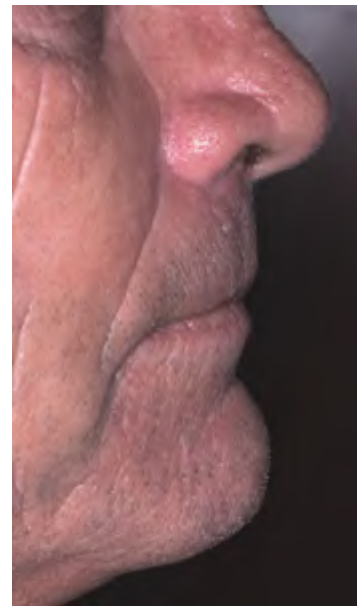


Figure 10.5. Clinical profile image of the patient with the existing maxillary denture in place at rest.



Figure 10.6. Clinical intraoral image of the patient's maxillary edentulous ridge approximately 12 months after bone grafting.

covered with plastic. He was not satisfied with the VDO, nor with the amount of lip support (Figures 10.4 and 10.5). He presented with a broad, U-shaped residual ridge with adequate amounts of fixed, keratinized gingiva (Figure 10.6).

RADIOGRAPHS

The panoramic radiograph demonstrated excellent osseous healing; there appeared to be adequate bone volume in the anterior and posterior maxillae for implants (Figure 10.7).

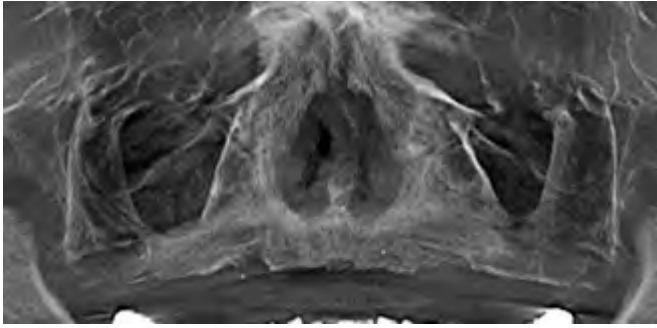


Figure 10.7. Panoramic radiograph prior to implant placement. There appeared to be adequate bone volume throughout the entire maxillae for the placement of multiple implants to support a fixed prosthesis.

DIAGNOSIS

The following diagnoses were established:

1. Edentulous maxillae with adequate bone volume for implant placement
2. Minimal anterior/posterior maxillary resorption
3. Unsatisfactory, somewhat ill-fitting maxillary denture
4. Inadequate VDO with altered occlusal plane
5. Inadequate lip support

ASSESSMENT

The patient appeared to have adequate bone volume for six to eight maxillary implants. The preexisting maxillary denture was not satisfactory in terms of tooth arrangement, occlusal plane, lip support, incisal display while smiling, VDO, and lip support. The best way to develop the most predictable treatment plan involved fabrication of a scanning appliance in order to assess the bone volume available for implant placement relative to the planned location of the teeth. However, because the preexisting maxillary denture was unsatisfactory, a new wax denture was needed prior to fabrication of the scanning appliance. If the CT scan provided evidence of adequate bone in the correct areas, it was likely that the patient could be restored with a fixed implant-retained prosthesis. If the bone was of sufficient quality and the implants achieved at least 40 Ncm of insertion torque, an immediate provisional prosthesis could be fabricated and inserted according to an immediate occlusal loading protocol.

TREATMENT PLAN

The treatment plan was divided into prosthetic, diagnostic and virtual treatment planning, laboratory, and clinical phases:

Prosthetic phase:

1. Construction of a maxillary wax denture with optimal lip support, incisal display, orientation of the occlusal plane, and VDO
2. Construction of a CT scanning appliance by duplicating the maxillary wax denture
3. Laboratory (articulator) fabrication of an interocclusal record with the scanning appliance in occlusion
4. Try in and adjust the scanning appliance

Diagnostic and virtual treatment planning:

1. CT scan with the scanning appliance and interocclusal record in place
2. Reformat the CT scan data
3. Virtual treatment planning regarding implant and abutment placement, consistent with the bone volume, planned teeth locations, and prosthesis design
4. Order the surgical guide
5. Evaluate the surgical guide
6. Try in the surgical guide and make an elastic jaw relation record with the guide in place

Laboratory phase:

1. Fabricate the master cast with implant analogs from the surgical guide
2. Mount the master cast/surgical guide against the mandibular cast
3. Place the preselected prosthetic components onto the implant lab analogs in the master cast
4. Wax the prosthesis, including a metal substructure
5. Cast the metal substructure
6. Process the acrylic resin prosthesis

Clinical phase:

1. Place the implants with the surgical guide and elastic jaw relation record
2. Place the abutments
3. Attach the prosthesis to the abutments and implants

CONSTRUCTION OF MAXILLARY WAX DENTURE

Diagnostic casts are accurate reproductions of all of the clinical features of dentulous or edentulous jaws. These include teeth; contours; occlusal plane location; residual ridge contour, size, and mucosal consistency; and the oral

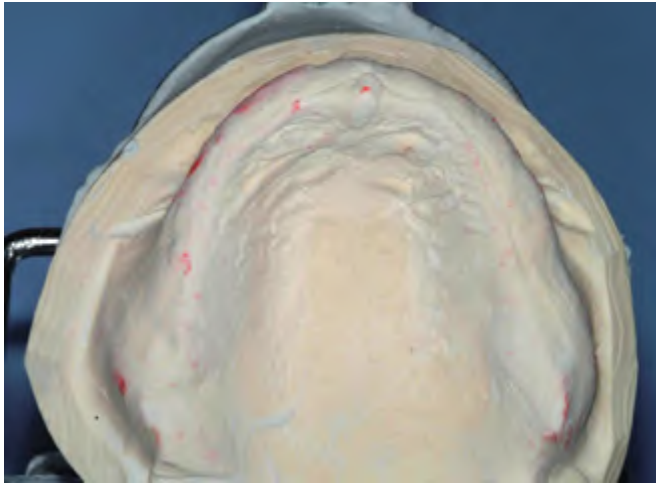


Figure 10.8. Laboratory occlusal image of the diagnostic maxillary cast.

anatomy that defines the extensions of removable prostheses such as vestibules, retromolar pads, pterygomaxillary notches, hard and/or soft palatal junction, floor of the mouth, and location and extent of frena. Once diagnostic casts have been mounted, the location and orientation of the occlusal plane and the tooth/ridge relationships (vertical and horizontal) can be much better visualized by clinicians and dental laboratory technicians. Record bases are needed in order to mount edentulous casts.

Diagnostic casts are usually made with dental stone, instead of plaster, due to its greater strength and abrasion resistance. A conventional diagnostic cast was made from an alginate impression in a stock impression tray (Figure 10.8).

Elder (1955) established the following requirements for record bases. They should:

1. Adapt to the basal seat areas as well as definitive denture bases
2. Have the same peripheral border form as definitive denture bases
3. Be rigid
4. Be dimensionally stable
5. Permit their use as bases for setting denture teeth
6. Be easy and inexpensive to fabricate
7. Be of an eye-pleasing color

This maxillary record base was fabricated from visible light-cured resin per the manufacturer's instructions (Triad®, Dentsply International, York, PA) (Figures 10.9 and 10.10).

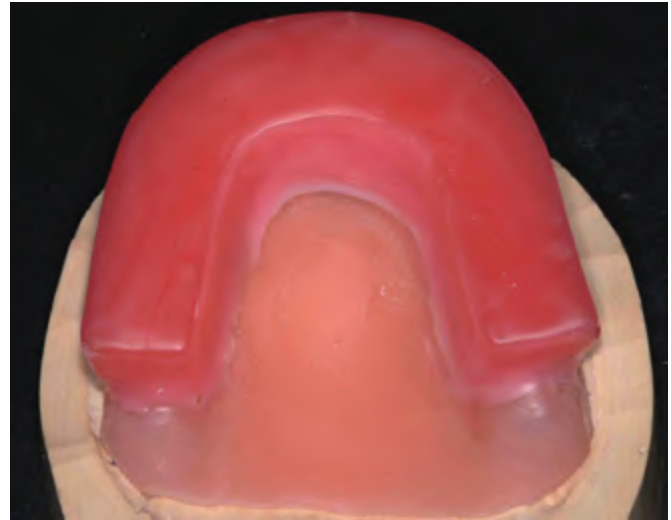


Figure 10.9. Laboratory image of the occlusal surface of the maxillary record base and occlusion rim.

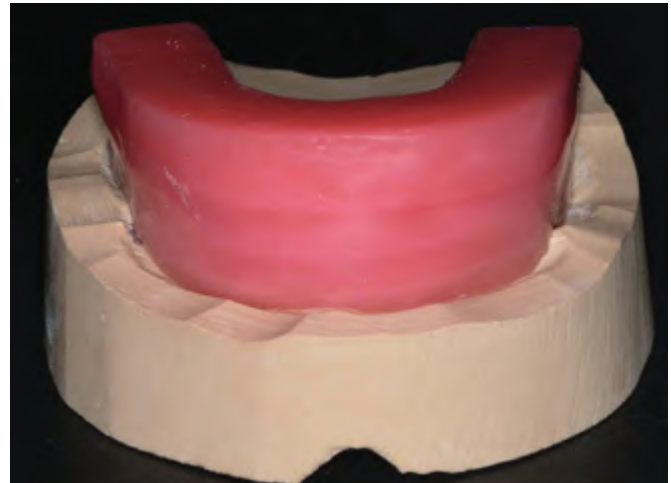


Figure 10.10. Laboratory image of the facial surface of the maxillary record base and occlusion rim.

The maxillary occlusal plane, lip support of the upper lip, and the amount of incisal display at rest, speaking, and smiling were initially established with the maxillary record base and occlusion rim. The initial VDO was established by using the mandibular teeth as the anterior stop on the maxillary record base. Once this was established, two posterior stops were made on the posterior segments of the maxillary occlusion rim with wax (Aluwax™, Aluwax Dental Products Co., Allendale, MI). The actual jaw relation record was made with the prosthodontist guiding the patient into a repeatable centric relation position. According to the manufacturer's Web site (www.aluwaxdental.com), Aluwax dental wax is a composite material that contains powdered aluminum. Powdered aluminum increases the integrity of the compound and provides heat-retention



Figure 10.11. Clinical image of the patient with the maxillary record base and occlusion rim in place. The centric jaw relation record was recorded with wax; the dental midline was marked on the facial surface of the occlusion rim.



Figure 10.12. Laboratory anterior view of the casts mounted in the articulator. The maxillary midline was centered medial/laterally, consistent with the incisal guide pin. The occlusal plane was placed in the middle of the upper and lower members of the articulator, parallel to the horizontal plane, with the incisal guide pin set at zero. The maxillary cast was mounted first; the mandibular cast was mounted to the maxillary cast. All of the mountings were made with mounting stone.

properties required for efficient modeling. Other materials, such as copper-based waxes, do not retain heat as long, and begin to harden quicker than clinicians may want. At this clinical appointment, the midline was marked on the maxillary occlusion rim and a tooth form and shade were selected. The patient was discharged to return for the initial wax try-in (Figure 10.11).

In this case, the casts were mounted arbitrarily in the articulator with the occlusal plane horizontal, the maxillary midline centered, and the casts in the middle of the simple hinge articulator (Figure 10.12). The casts were mounted with mounting stone (Whip Mix Corp., Louisville, KY) mixed according to the manufacturer's instructions.

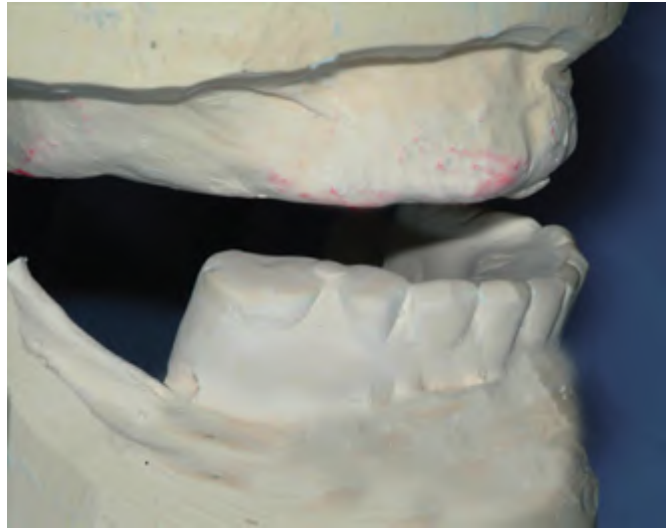


Figure 10.13. Right buccal laboratory view of casts mounted in the articulator. The casts were mounted so that the occlusal plane was horizontal and in the middle of the upper and lower members of the articulator.



Figure 10.14. Left buccal laboratory view of casts mounted in the articulator. The casts were mounted so that the occlusal plane was horizontal and in the middle of the upper and lower members of the articulator.

In this case, Justi Blend® acrylic resin anterior and 20-degree Anatomical Justi Blend® posterior teeth were selected (Justi Products, Oxnard, CA).

In order to evaluate the amount of anterior/posterior maxillary resorption that had occurred relative to the mandibular anterior teeth, the maxillary record base and occlusion rim were removed from the maxillary cast (Figures 10.13 and 10.14). This patient had undergone minimal anterior/posterior resorption (less than 9mm), and was therefore,



Figure 10.15. Laboratory anterior view of the maxillary wax denture in the articulator, ready for try-in.



Figure 10.16. Laboratory right buccal view of the maxillary wax denture in the articulator, ready for try-in. At this time, the posterior teeth were set for maximum intercuspation.

based on the articulator mounting, a candidate for a fixed prosthesis.

The teeth were set consistent with the contours of the maxillary occlusion rim on the record base for the wax try-in. Twenty-degree teeth were used in the posterior segments. These teeth were set for optimal centric contacts and group function occlusion in right and left working movements (Figures 10.15–10.18).

CLINICAL TRY-IN OF THE MAXILLARY WAX DENTURE

The patient, his spouse, and the author evaluated the aesthetics, lip support, occlusal vertical dimension, and rest vertical dimension of the maxillary wax denture at the



Figure 10.17. Laboratory left buccal view of the maxillary wax denture in the articulator, ready for try-in. The posterior teeth were set for maximum intercuspation.



Figure 10.18. Laboratory occlusal view of the maxillary wax denture.

wax try-in appointment. The author evaluated and confirmed the accuracy of the jaw relation record per the above parameters. The patient and his spouse agreed to the aesthetics of the maxillary wax denture (Figures 10.19 and 10.20).

FABRICATION OF THE SCANNING APPLIANCE

The maxillary wax denture was flaked in conventional fashion in a two-piece denture flask (Figure 10.21). Dental stone was vacuum mixed and vibrated into the bottom half of the flask. The maxillary wax denture was placed into the stone (intaglio surface down). The stone ended at the land



Figure 10.19. Clinical anterior image of the patient with the maxillary wax denture during speech. This image demonstrated that there was adequate interocclusal clearance between the maxillary and mandibular anterior teeth during speech.



Figure 10.20. Clinical profile image of the patient with the maxillary wax denture during speech. This image demonstrated that there was adequate interocclusal clearance between the maxillary and mandibular anterior teeth during speech.

area of the cast. A separating material (Isodent, Kerr Manufacturing Co., Romulus, MI) was mixed, applied to the stone in the flask and the wax denture, and allowed to dry. A thin mix of polyvinyl siloxane impression material was placed over the wax denture and teeth. This provided a smooth surface to the scanning appliance. The top part of the flask was placed onto the bottom part of the flask and additional dental stone was vacuum mixed and poured into the top part of the flask. The lid was placed and the stone was allowed to set. The two portions of the flask were separated, and the wax denture was removed (Figure 10.22).



Figure 10.21. Laboratory occlusal image of the wax denture inside the denture flask, after the initial mix of stone was placed. A thin layer of polyvinyl siloxane impression material will be placed over the occlusal surfaces of the teeth and maxillary denture prior to the second dental stone pour.



Figure 10.22. Laboratory occlusal image of the wax denture mold inside the denture flask. The polyvinyl siloxane impression material that had been placed in a thin layer over the occlusal surfaces of the teeth and maxillary denture remained in the bottom half of the denture flask after the boil-out process. This provided a smooth surface to the scanning appliance.



Figure 10.23. Laboratory image of the labial surface of the scanning appliance after polishing.

A mixture of 30% barium sulfate (E-Z-HD Barium Sulfate For Suspension 98%W/W, E-Z-EM Canada, Inc., a subsidiary of E-Z-EM Inc., Westbury, NY, USA) and tooth-colored autopolymerizing acrylic resin (Jet Tooth Shade 6/1 Kit, Land Dental Manufacturing Co, Inc., Wheeling, IL) was mixed and vibrated into the impression (mold) of the occlusal surfaces of the maxillary wax denture in the flask. Immediately after that material was vibrated into the flask, a new mix that consisted of 10% barium sulfate and autopolymerizing acrylic resin was mixed and vibrated into the mold, on top of the previous mixture. The flask was closed and placed into a flask press, and the mixture was allowed to polymerize. The flask was opened and the scanning appliance was removed, without damaging the master cast. It was finished and polished in conventional fashion with burs and flour of pumice (Figures 10.23 and 10.24).

Any remaining internal undercuts were removed from the scanning appliance, and the appliance was fitted back onto the master cast. The casts were rearticulated, and the processing error was adjusted on the scanning appliance. After the adjustment, a laboratory interocclusal record was made with polyvinyl siloxane impression material (Figure 10.25). Clinically, the scanning appliance was fitted to the patient's mouth and adjusted as needed to make sure that it was comfortable. The interocclusal record was verified as accurate. The scanning appliance and the interocclusal record were sent to the implant surgeon for the in-office CBCT scan.

INTRAORAL CT SCAN

The CT scan was accomplished without incident. One major benefit of CT-guided surgery is that the implant surgeon can precisely identify the locations of vital anatomical structures, the amount of viable bone for implant placement, and the planned location of the artificial teeth



Figure 10.24. Laboratory image of the occlusal surface of the scanning appliance after polishing.



Figure 10.25. Laboratory illustration of a scanning appliance on a maxillary cast, laboratory fabricated interocclusal record, and a mandibular cast mounted in an articulator. The interocclusal record was made after the processing error was adjusted for.

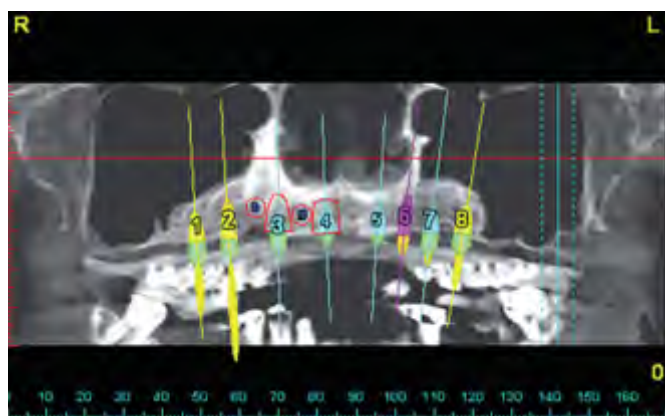


Figure 10.26. A computer screen shot of the panoramic image of the CBCT scan. Eight implants were planned for this patient. The implants were numbered by the software manufacturer in order of placement (maxillary right posterior quadrant to the maxillary left posterior quadrant, 1 through 8). The anterior teeth were not visible in this particular frontal slice. Implants numbered 1, 2, and 8 were 5-mm-diameter implants; the other implants were 4.1-mm- and 3.25-mm-diameter implants.

in the prosthesis prior to surgery (Figure 10.26). Virtual implants are available for multiple implant manufacturers and can be determined in terms of implant/abutment connection, diameter, length, and 3-D orientation. If abutments are to be used, the collar height, type, and amount of angle correction can also be determined (Figures 10.27–10.31).

Once the treatment planned was decided on by the implant team, the data were e-mailed to Materialise Dental at www.materialisedental.com for fabrication of the surgical guide and the treatment plan (Figures 10.32–10.34). In this case, SimPlant 12.02 (Materialise Dental Inc., Glen Burnie, MD) was the software program used.

FABRICATION OF THE MASTER CAST WITH IMPLANT ANALOGS

SLA surgical guides provide the link between the treatment plan that was developed with the software program and the actual surgical positioning of the implants. The guide manufacturer placed the master tubes, consistent with the

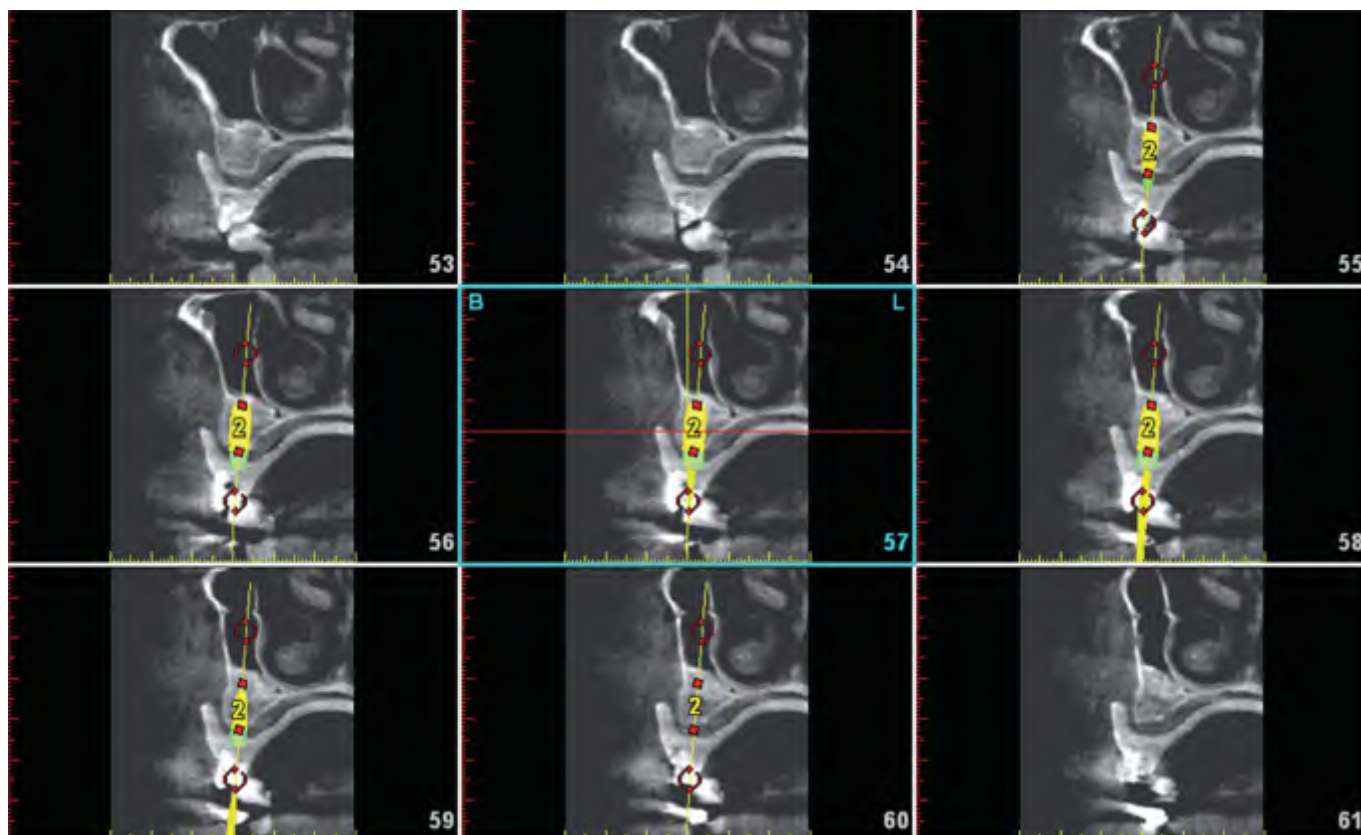


Figure 10.27. Screen shot of the right posterior maxilla with a virtual 5-mm-diameter implant (implant #2) in place (slices 55 through 59). The virtual implant was placed within the alveolar bone and centered within the tooth form on the scanning appliance so that the screw access opening would be located within the occlusal surface of the prosthesis.

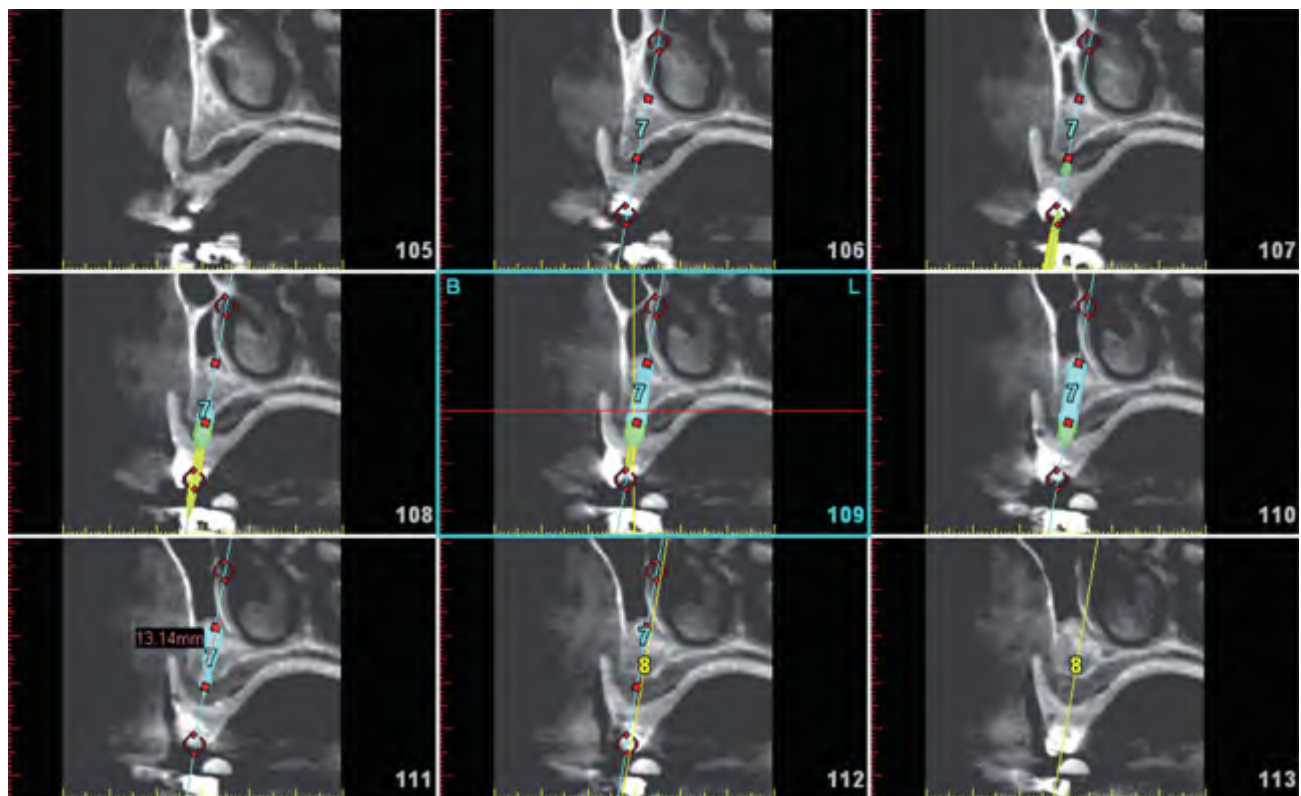


Figure 10.28. Screen shot of the left posterior maxilla with a virtual 4-mm-diameter implant in place (slices 108 through 111). The virtual implant was placed within the alveolar bone and centered within the tooth form on the scanning appliance so that the screw access opening would be located within the occlusal surface of the prosthesis.

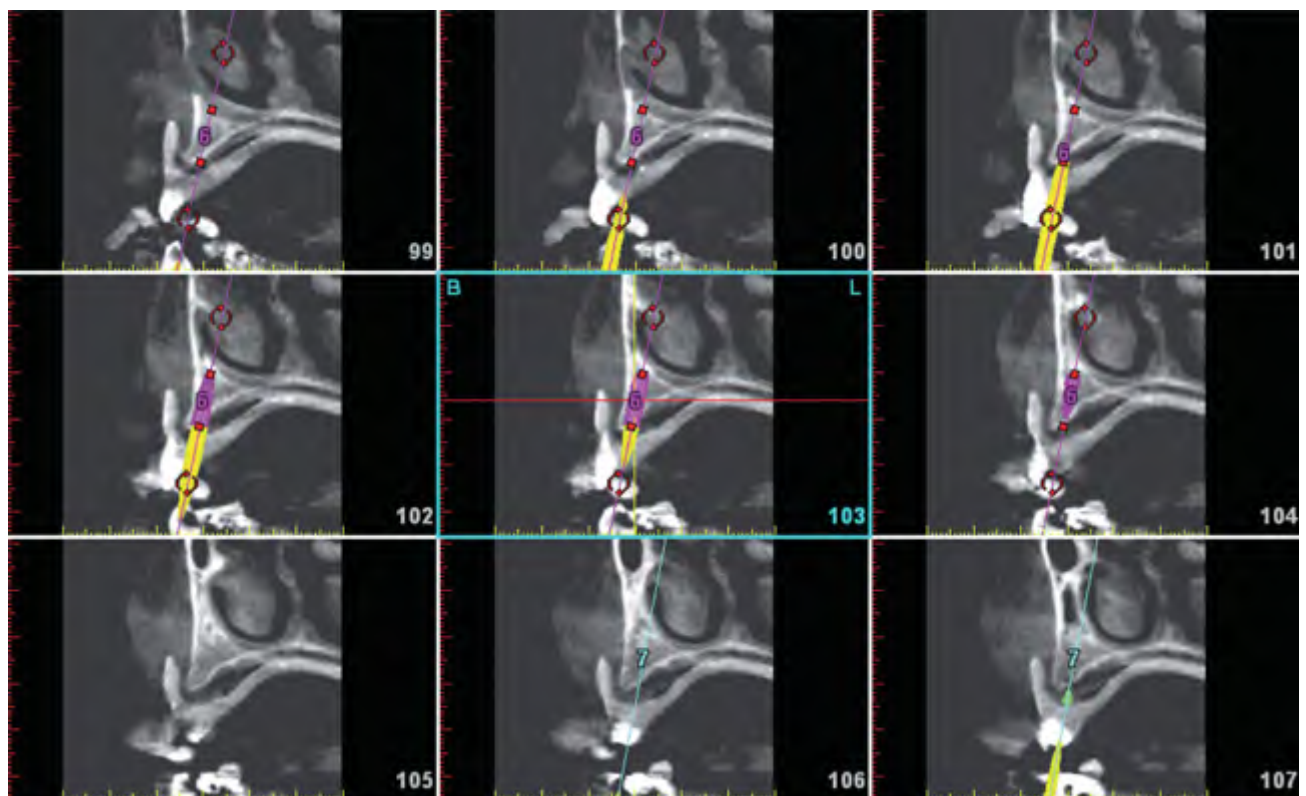


Figure 10.29. Screen shot of the left anterior maxilla with a virtual 3.25-mm-diameter implant in place (slices 102 through 104). The virtual implant was placed within the alveolar bone and centered within the tooth form on the scanning appliance so that the screw access opening would be located within the occlusal surface of the prosthesis. A 3.25-mm-diameter implant was planned in this space due to insufficient buccal/palatal bone width.

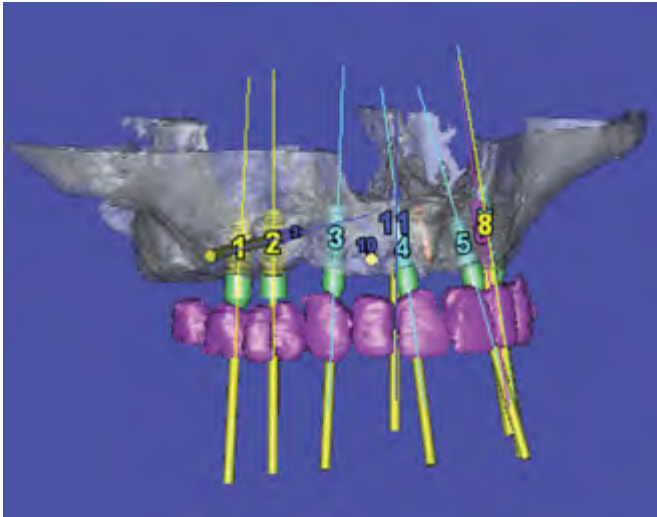


Figure 10.30. Three-dimensional screen shot that identified the planned locations of the teeth within the prosthesis as well as the locations of the implants. All of the implants were placed such that they were contained within the corresponding teeth.

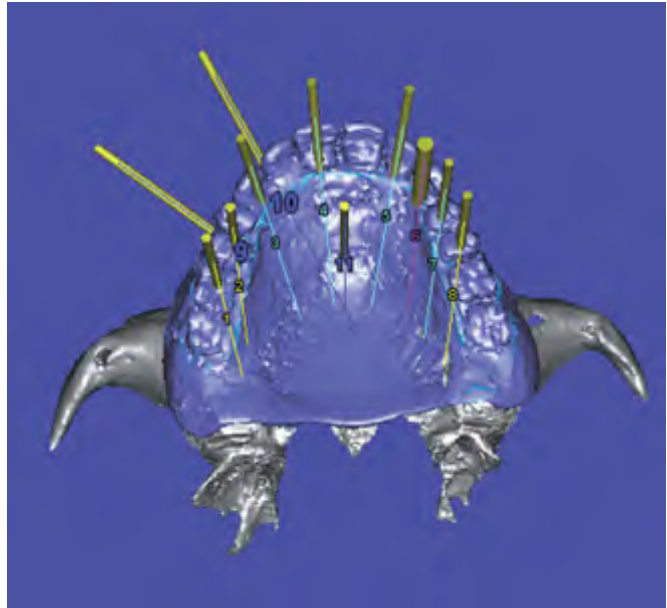


Figure 10.31. Screen shot of the occlusal surface of the maxillae. All of the virtual implants were centered within the tooth forms of the scanning appliance so that the screw access openings were located within the occlusal surfaces of the prosthesis. Implants #9 and 10 were the horizontal fixation screws. Implant #11 was a vertical fixation screw that was placed into the palate, as there was not enough room to place it horizontally without compromising one of the supporting implants.



Figure 10.32. Laboratory view of the intaglio surface of the maxillary stereolithographic surgical guide as received from Materialise Dental. The blue master tubes were for 4-mm-diameter implants; the gold master tubes were for 5-mm-diameter implants.



Figure 10.33. Laboratory view of the occlusal surface of the maxillary stereolithographic surgical guide as received from Materialise Dental. The blue master tubes were for 4-mm-diameter implants; the gold master tubes were for 5-mm-diameter implants. The notches on each master tube were clearly evident.

BIOMET 3i Navigator™ Systems for CT Guided Surgery

UR UL

Implant Label	1	2	3	4	5	6	7	8
Implant	IFOS510	IFOS511	IFOS411	IFOS485	IFOS485	IFOSM311	IFOS413	IFOS510
Planned implant	5/3.1	5/3.1	4.1/2.6	4.1/2.6	4.1/2.6	3.4/2.4	4.1/2.6	5/3.1
Planned implant	9.6	11.1	11.1	8.1	8.1	11.1	12.6	9.6
Implant Placement								
Depth Line	(1)	(2)	(2)	(2)	(2)	(2)	(1)	(3)
Tissue Punch	5	5	4	4	4	4	4	5
Starter Drill	5	5	4	4	4	3	4	5
Drill / Handle	2(A)/3	2(B)/3	2(B)/1	2(A)/1	2(A)/1	2(B)/1	2(B)/1	2(B)/3
Drill / Handle	3.25(A)/4	3.25(B)/4	3(B)/2	3(A)/2	3(A)/2	2.75(B)/1	3(B)/2	3.25(B)/4
Drill / Handle	3.85(A)/4	3.85(B)/4	7	7	7	7	7	3.85(B)/4
Tap	5	5	4	4	4	3	4	5
Implant Mount	5(1)	5(2)	4(2)	4(2)	4(2)	3(2)	4(1)	5(3)
Bone Profiler	5	5	4	4	4	3	4	5
Analog Placement								
Analog Mount	5(1)	5(2)	4(2)	4(2)	4(2)	3(2)	4(1)	5(3)
Analog Type	HLAW5	HLAW5	HLA20	HLA20	HLA20	HMM1A	HLA20	HLAW5

Please note that the final drill diameters are recommended for use in medium bone densities. In soft or dense bone scenarios the osteotomy should be sized in accordance with BIOMET 3i standard drilling protocols, and the corresponding Navigator Drill Positioning Handle should be selected.

Figure 10.34. This is a copy of the treatment plan as received from Materialise Dental. The implant numbers correspond to the sequence of the implants in the order that they were treatment planned (1–8) and were not related to tooth sites. The dental laboratory technician wrote “UR” to indicate the maxillary right quadrant and “UL” to indicate the maxillary left quadrant. The prosthetic portion of the treatment plan was indicated on the last two lines under “Analog Placement.”



Figure 10.35. Illustration of 4-mm-diameter master tubes (4-mm length, left; 5.5-mm length, right). The notches (180 degrees apart) were machined for precise positioning of the implant analogs in the master cast.

diameters of the implants to be placed and the digitized treatment plan, precisely within the surgical guide (Figure 10.35). The master tubes transfer the implant locations from the plan to the patient by accurately guiding the requisite drills and implants into their predetermined locations, orientations, and positions. The implant team was not responsible for selecting the correct master tubes. This was determined by the software program.

Analog mounts may be purchased separately or in the prosthetic kit (Figure 10.36). Analog mounts are available



Figure 10.36. Top view of the laboratory prosthetic kit that contains the analog mounts. The mounts are arranged for 3.4-mm-diameter implants in the top section, 4.1-mm-diameter implants in the middle section, and 5-mm-diameter implants in the bottom section. The mounts are also arranged according to prolongation lengths: 1, 2, 3, and 4. It is critical for dental laboratory technicians to correctly identify the mounts according to the computer-generated prosthetic treatment plan.



Figure 10.37. Analog mounts in increasing prolongation lengths 1–4 (left to right).

in three diameters—3.4, 4.1, and 5mm—and have been manufactured in four different prolongation lengths (1, 2, 3, and 4) (Figure 10.37). The appropriate analog mounts were selected, consistent with the instructions on the treatment plan, and attached to their corresponding implant analogs (Figure 10.38).

The implant analogs were placed into their respective analog mounts, the hexes were lined up and the thumbscrews were threaded for approximately two turns. The analog mount/implant analog complexes were then placed into their respective master tubes, and the positioning pins were lined up between the analog mounts and the master tubes by placing the positioning pins into the notches. The thumbscrews were hand tightened (Figures 10.39–10.41). It must be noted that overtightening the analog mounts outside of the master tubes may damage the analog mounts.

A base was made from polyvinyl siloxane impression material by placing the occlusal surface of the surgical guide into the impression material (Figure 10.42). A



Figure 10.38. The implant analogs and analog mounts aligned in order from the maxillary right posterior quadrant to the maxillary left posterior quadrant (left to right). The prosthetic portion of the computer-generated treatment plan has been placed along the inferior edge of the image.

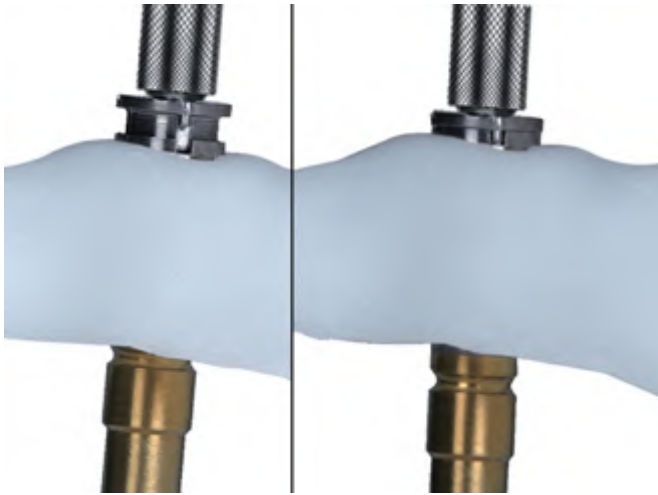


Figure 10.39. The illustration on the left demonstrates the analog mount/analogue complex not seated into the master tube. The illustration on the right demonstrates the analog mount/analogue complex seated correctly into the master tube.



Figure 10.40. Laboratory image of one implant analog/analogue mount pulled through a master tube in the surgical guide.

separating medium was placed onto the intaglio surface of the surgical guide; polyvinyl siloxane impression material was injected onto the surface of the surgical guide and around the implant analogs. The impression material provided a smooth surface to the cast. The “impression” was boxed and poured with vacuum-mixed die stone (Figures 10.43 and 10.44). After the stone set, the thumbscrews were unscrewed, and the analog mounts were removed. The surgical guide was carefully removed from the master cast (Figure 10.45).



Figure 10.41. Laboratory image of the implant mount/implant analogue complexes seated in their correct positions within the surgical guide.



Figure 10.42. Polyvinyl siloxane impression material was used to make a base and the land areas prior to boxing the surgical guide.

The wax denture (the scanning appliance may also be used) was fitted onto this cast, and the cast was mounted in the articulator with the preexisting laboratory fabricated interocclusal record (Figures 10.46 and 10.47).

LABORATORY ABUTMENT SELECTION AND PLACEMENT

An alginate impression was made of the maxillary wax denture and poured in dental stone (Figure 10.48). A Biostar® machine (Great Lakes Orthodontics, Tonawanda, NY) was used to create a rigid plastic mold duplicate of



Figure 10.43. Additional polyvinyl siloxane impression material was injected onto the intaglio surface of the surgical guide and around the implant analogs and implant mounts to replicate the maxillary soft tissues.



Figure 10.44. Laboratory occlusal image of the surgical guide after the cast was poured and the stone set. The thumbscrews were loosened and removed, much as one loosens impression coping screws in a conventional implant impression.

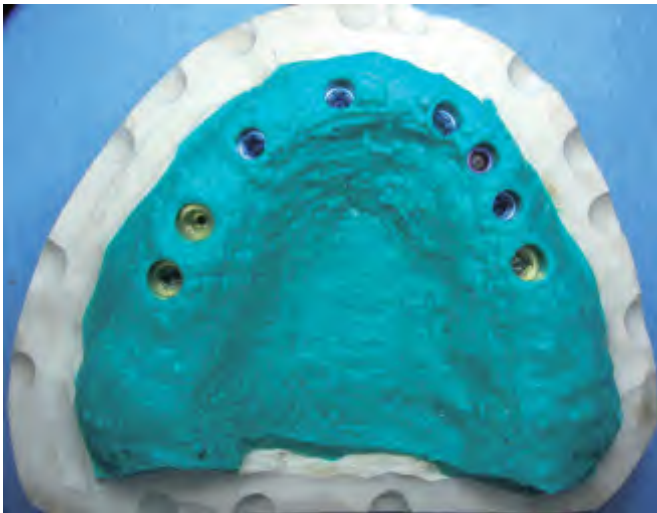


Figure 10.45. This is an occlusal view of the definitive maxillary master cast after it was separated from the surgical guide. The implant analogs were in the precise positions as determined with the software program and other diagnostic efforts.



Figure 10.46. Laboratory occlusal image of the maxillary wax denture in place on the master cast created from the surgical guide.



Figure 10.47. Left laboratory view of the silicone index and interocclusal record of the maxillary wax denture after the patient had given his approval regarding aesthetics, vertical dimension, and lip support. This index was used to mount the maxillary wax denture on the master cast made from the surgical guide against the previously mounted mandibular cast.



Figure 10.48. Laboratory occlusal image of the maxillary diagnostic cast.

the maxillary denture (Figure 10.49). The plastic mold was placed onto the maxillary master cast (Figure 10.50).

Two nonhexed screw-retained cylinders (IITCS42, Biomet 3i) were to be used in the cuspid implants (Figure 10.51).

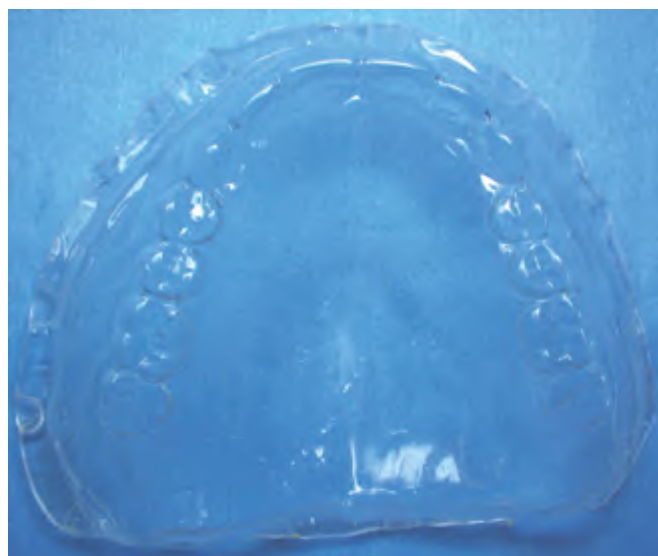


Figure 10.49. Rigid plastic mold made from the maxillary diagnostic cast in Figure 10.48.



Figure 10.50. Laboratory occlusal image of the rigid plastic mold in place on the maxillary master cast. Holes were cut into the plastic mold for placement of the implant temporary cylinders (IITCS42) onto the implant laboratory analogs.

Nonhexed cylinders are designed to be used with splinted, multiple-unit restorations. These cylinders are designed with physical retentive elements that facilitate mechanical attachment of acrylic resin to them during the clinical pick-up procedures. One of these would be processed into the provisional prosthesis in the laboratory; one would be picked up with acrylic resin intraorally. The cylinders are also designed so that acrylic resin can be added to the apical portions of the cylinders to facilitate optimal subgingival contours. The cylinders were secured into the implant

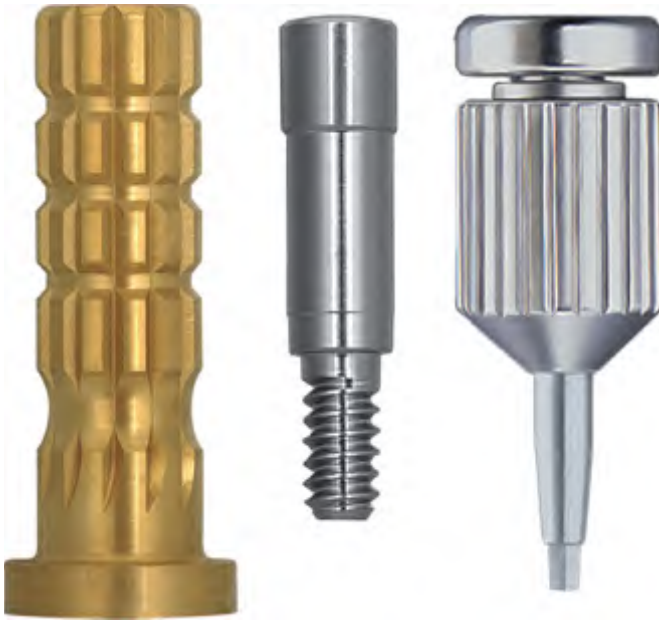


Figure 10.51. Multiunit (nonhexed) implant temporary cylinder, IITCS42 (left); large-diameter titanium abutment screw, ILRGHT (center); large hex driver, PHD02 (right).



Figure 10.52. Conical abutments with 2- and 3-mm collar heights (ICA002, ICA003).

lab analogs with large-diameter titanium abutment screws (ILRGHT, Biomet 3i) for nonhexed cylinders and the large hex driver (PHD02, Biomet 3i).

The other implants lined up nicely with the teeth in the plastic mold; it was decided to use conical abutments (ICA002, ICA003, Biomet 3i) and QuickBridge® components that featured titanium cylinders and polyetherether ketone (PEEK) caps for cement retention (QuickBridge, Biomet 3i) (Figures 10.52–10.54).



Figure 10.53. QuickBridge components as received from Biomet 3i. Conical abutment (lower left); titanium cylinder in place (lower left); PEEK cap above the titanium cylinder (upper left); PEEK cap in place on titanium cylinder already attached to the conical abutment (right).

One of the goals in this case in the treatment planning process was to locate the margins of the maxillary abutments slightly subgingival, post implant placement. The QuickBridge components add one additional millimeter to the prosthetic components. Therefore, 2- and 3-mm conical abutments were placed into their respective positions on the maxillary analogs.

A silicone index of the wax denture had been made after the patient had agreed to the aesthetics and VDO (Figure 10.55). From the diagnostic workup with the software program, the implant team knew that angle corrections were not needed for any of the maxillary implants. This specific prosthesis was designed with both screw- and cement-retained components (Figure 10.56).

FRAMEWORK FABRICATION (PROVISIONAL PROSTHESIS)

Since the patient indicated to the surgeon that he wanted to wear this prosthesis for at least 18 months, it was decided to reinforce the provisional prosthesis with a cast metal framework. The maxillary provisional prosthesis was waxed to full contour (Baseplate Wax Sheets, Keystone Industries, Myerstown, PA), simulating the contours of the wax denture (Figure 10.57). The author has found that using baseplate wax decreases the time required to wax full-arch prostheses. The wax pattern was cut back, sprued, and cast with a base metal alloy (Wiron® 99, Bego, Konstantz, Germany) (Figure 10.58). Wiron 99 is a corrosion-resistant, base metal alloy with a high modulus of elasticity (Table 10.1).



Figure 10.54. Conical abutment (upper left); QuickBridge components (lower left); maxillary master cast with plastic mold and restorative components in place; implant temporary cylinder (upper right). Holes had been prepared into the plastic mold to facilitate access to the abutment screws.

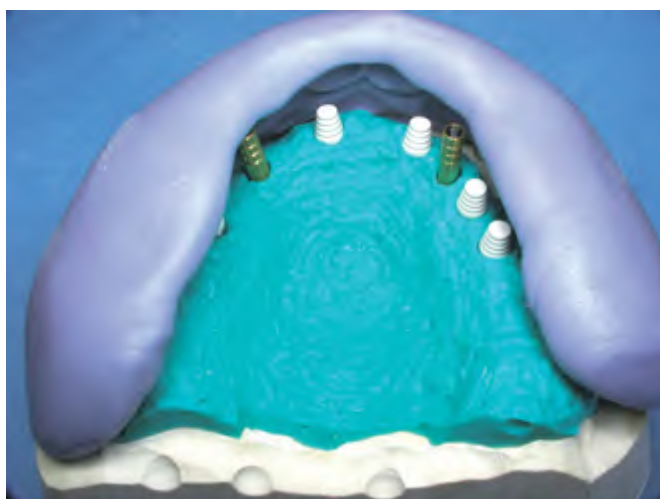


Figure 10.55. Silicone index, made from the maxillary denture, in place on the maxillary cast. The restorative components were in place.



Figure 10.56. Laboratory occlusal view of the implant restorative components used in the maxillary right posterior quadrant. The most distal implant analog has a 2-mm conical abutment, QuickBridge titanium cylinder, and PEEK cap in place; the PEEK cap was snapped onto the titanium cylinder. The middle implant analog has a 2-mm conical abutment and QuickBridge titanium cylinder screwed in place. The anterior implant analog has a nonhexed implant temporary cylinder in place.



Figure 10.57. Laboratory labial view of the full-contour wax patterns on the maxillary master cast. The implant restorative components as noted in Figure 10.56 were in place beneath the wax patterns.

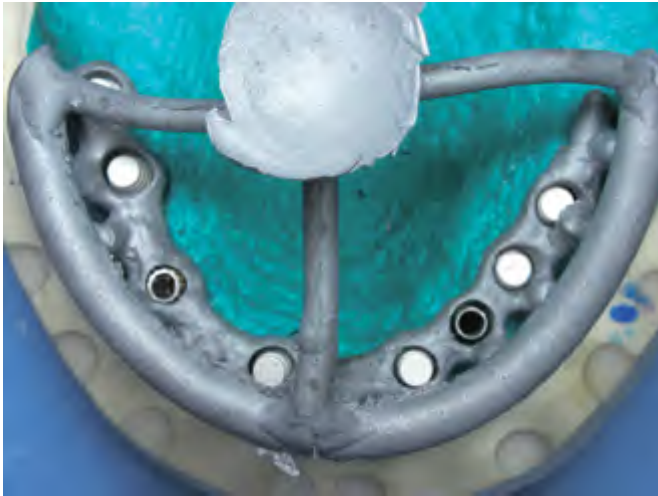


Figure 10.58. Occlusal image of the maxillary casting in place around the maxillary implant restorative components. The right temporary cylinder was soldered to the framework.

To decrease the labor associated with a 12-unit framework, the framework was not waxed to be cast directly to the implant restorative components. Instead, it was waxed so that the framework copings encircled the maxillary components (Figure 10.59). One implant temporary cylinder was soldered to the framework. The space between the other restorative components and the framework would be filled in with autopolymerizing acrylic resin clinically. After the implants were placed and the surgical guide removed, all of the restorative components would go to place onto the implants per the treatment plan. The framework would be screwed into place on the maxillary right cuspid implant. By design, the framework would not engage any of the other restorative components, as there would be



Figure 10.59. Laboratory occlusal image of the maxillary casting in place around the maxillary implant restorative components. The framework was finished, polished, and opaqued with a tooth-colored acrylic resin opaque. The framework was only attached to the right temporary cylinder; space was provided between the framework and the remaining components, as they would be picked up with acrylic resin intraorally.

TABLE 10.1. Physical Properties and Characteristics of Wiron 99

	Standard Values
Color	Silver
Density	8.2 g/cc ³
Melting range	1250–1310°C
Casting temperature	Approximately 1420°C
Coefficient of thermal expansion	
20–600°C	14.0 · 10 ⁻⁶ /K
25–500°C	13.8 · 10 ⁻⁶ /K
Ductile yield	25%
Elongation limit	330 MPa
Thermal contraction (solidus to room temp)	Approximately 2.2%
Modulus of elasticity	Approximately 205,000 MPa
Vickers hardness after casting	180
Composition by weight	
Ni	65%
Cr	22.5%
Mo	9.5%
Nb	1%
Si	1%
Fe	0.5%
Ce	0.5%
C	0.2% (max)

Note: From Directions for Use, Wiron 99.



Figure 10.60. Laboratory intaglio view of the silicone mold made from the full-contour maxillary wax patterns.

space between the components and the framework. Resin would then be used to attach the QuickBridge PEEK caps and the other implant temporary cylinder to the framework at the clinical appointment. This significantly decreased the complexity of the framework and resulted in decreased costs to the clinicians and patient. The framework was opaqued, finished, and polished.

PROVISIONAL PROSTHESIS

A mold had been made of the full-contour wax patterns prior to the wax cut back (Figure 10.60). Acrylic resin has been reported to have a linear contraction of approximately 0.1%–0.15% (Dixon and others 1992). It was considered unlikely that the processed provisional prosthesis would go directly to place intraorally. The definitive, passive fit of the maxillary provisional prosthesis would be provided by the clinical pick-up after the implants were in place. The screw access openings were sealed with wax. All mechanical retentive elements of the implant temporary components were blocked out with wax. Autopolymerizing acrylic resin was mixed and injected into the mold (DVA C&B Resin Plus, Indenco Dental Products, Corona, CA). The mold was seated into the indexes in the land area of the maxillary master cast, placed into a pressure pot, and allowed to polymerize. The silicone index was removed (Figures 10.61 and 10.62). All of the maxillary restorative components remained in place on the laboratory analogs and were not picked up inside the provisional prosthesis. Boiling water was used to remove the block out wax from the prosthetic components in the cast.

The provisional prosthesis was rearticulated, and the occlusion was adjusted. Since the patient had lost a mod-



Figure 10.61. Laboratory occlusal image of the processed acrylic resin maxillary provisional prosthesis. Note the screw access opening for the maxillary right cuspid implant temporary cylinder.



Figure 10.62. Laboratory facial image of the processed acrylic resin maxillary prosthesis in place on the maxillary cast.

erate amount of maxillary alveolar bone, it was felt that without gingival-colored acrylic resin simulating normal gingival architecture, the teeth on the provisional prosthesis would be too long. Therefore, tooth-colored acrylic resin was removed from areas that corresponded to the gingival contours surrounding natural teeth and replaced with gingival colored acrylic resin (Dentsply Repair Material, Dentsply International). It was mixed and applied with a metal instrument. The resin was cured in a pressure pot for 10 minutes under 20psi (Figure 10.63). Spaces were provided in the intaglio surface of the provisional prosthesis for the clinical portion of the prosthetic procedures (Figure 10.64). The provisional prosthesis was finished and polished (Figure 10.65).

The clinical plan was to place all of the implants, temporary cylinders, conical abutments (with the QuickBridge com-



Figure 10.63. Laboratory facial image of the processed acrylic resin maxillary prosthesis in place on the maxillary cast with gingival-colored acrylic resin in place.



Figure 10.64. Laboratory intaglio image of the processed acrylic resin provisional prosthesis. Spaces were provided to accommodate the implant restorative components for the clinical pick-up procedures.



Figure 10.65. Laboratory facial image of the processed acrylic resin maxillary prosthesis in place on the maxillary cast with gingival-colored acrylic resin. The prosthesis was finished and polished; it was now ready to be shipped to the clinicians.

ponents) into their respective positions. After the prosthetic components were in place, the prosthesis (with the implant temporary cylinder in the right cuspid implant site) would be screwed into the cuspid implant on the right side. The prosthesis would be evaluated to make sure that no other prosthetic components touched the provisional prosthesis. Adjustments would be made as needed to ensure that there were no interferences. Then, autopolymerizing acrylic resin would be added to the screw-retained implant temporary cylinder in the left cuspid site and allowed to set. The prosthesis would be removed and the excess acrylic resin would be removed. Additional acrylic resin would then be mixed and injected into the spaces provided in the prosthesis that corresponded to the other temporary cylinders and QuickBridge components. The provisional prosthesis would be screwed into the two maxillary cuspid implants, and the patient would be guided into centric occlusion. The resin would be allowed to polymerize. The provisional prosthesis would be removed, finished, polished, and reinserted.

The maxillary provisional prosthesis, abutments, cylinders, and screws were packaged for shipping. An itemized list was written for the clinicians that identified the specific components for each specific implant (Figure 10.66). The case was shipped to the clinicians prior to the surgical/prosthetic appointment.

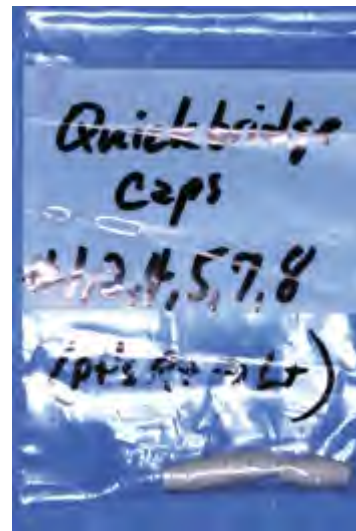


Figure 10.66. This is one example of how the implant restorative components were shipped from North Shore Dental Laboratories to the surgical office. This type of complex treatment involves numerous restorative components that may be easily misplaced during the surgical and prosthetic procedures. Precise labeling decreases the potential for these types of errors occurring.



Figure 10.67. Clinical image of the patient on the day of surgery, just prior to receiving the local anesthetic injections.



Figure 10.68. Clinical image with the surgical guide and interocclusal record in place. The surgical guide was thought to be completely seated by virtue of the patient occluding into the interocclusal record. The author felt that this method of securing the surgical guide in place was more accurate than having the surgeon hold the guide in place while drilling the osteotomies for the fixation screws.

SURGICAL IMPLANT PLACEMENT

The surgeon injected an appropriate amount of local anesthetic into all of the edentulous maxillary segments (Figure 10.67). He placed the surgical guide with the laboratory fabricated interocclusal record (Figure 10.68). By having the patient occlude into the interocclusal record, the clinician was assured that even pressure was generated through the surgical guide and that the surgical guide was completely and evenly seated against the mucosal tissues. The surgeon completed the specific sequence for each implant site per the surgical plan provided by the guide manufacturer (Figures 10.69–10.72).

The surgical portion of the treatment was completed; the implants were considered to be in the positions established in the master cast and the surgical guide (Figure 10.73).



Figure 10.69. Surgical image of the pilot drill in the surgical guide. The pilot drill follows the tissue punch (not pictured). The pilot drill was used to perforate the cortical plate in each implant site. Illustration of tissue punch and starter drill (left to right; inset).

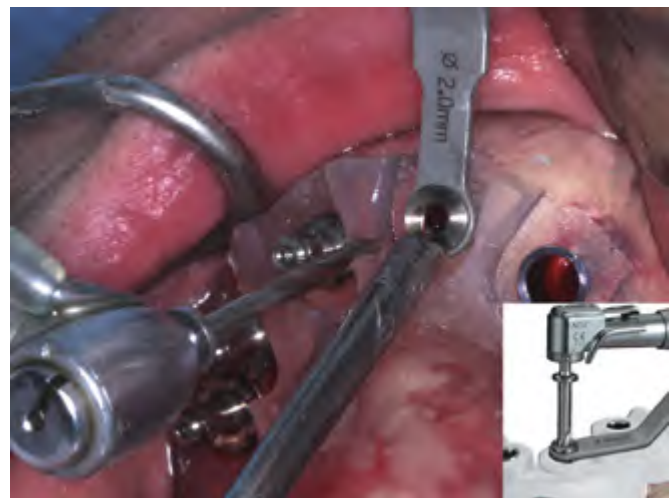


Figure 10.70. Surgical image of the drill handle in place in the surgical guide. This drill handle was designed for use with the 2-mm twist drill. The drill handle changed the diameter of the 4-mm master tube to 2-mm for the 2-mm twist drill. If the drill handle was not used, the surgeon would not be able to put the 2-mm twist drill concentrically within the master tube, and the location of the osteotomy would not be consistent with the planned location. Inset in the lower right part of the image is an illustration of a 2.75-mm twist drill in place, in a 2.75-mm drill handle, within a 4-mm-diameter master tube.

CLINICAL ABUTMENT PLACEMENT

Each specific conical abutment was selected for use in each specific implant as designated on the treatment plan. Each abutment was pressed into place until the click was felt and heard for each implant/abutment connection. The



Figure 10.71. Surgical image of a 3-mm drill handle in place within the surgical guide. The surgeon will seat a 3-mm twist drill completely within the master tube. The drill length was predetermined in the treatment plan. The drill cannot go too deep, as a metal flange was machined into the drill shaft to preclude it from going deeper than intended.



Figure 10.73. Clinical image of the occlusal surface of this patient's edentulous maxillae after removal of the surgical guide. Since the procedure was flapless, there was a minimal amount of blood in the surgical field.



Figure 10.72. Clinical image of the surgical guide in place after all implants were placed. The implant mounts are visible within the occlusal surface of the surgical guide. The notches in the implant mounts were in line with the notches of the master tubes and indicated that the hex timings that were present in the laboratory were transferred to the implants intraorally.



Figure 10.74. Clinical occlusal image of the patient with conical abutments and QuickBridge titanium cylinders in place. The implant in the right cuspid site did not have a restorative component in place, as it was already in the provisional prosthesis. The center inset illustrates a conical abutment on the left and a conical abutment with a QuickBridge titanium cylinder in place on the right. The upper right inset demonstrates a QuickBridge titanium cylinder being carried to an abutment with a large hex driver.

conical abutment screws were threaded into the implants using the abutment driver. The abutment screws were torqued to 20Ncm with an abutment driver tip and torque device. QuickBridge titanium temporary cylinders were threaded into the conical abutment screws using the large hex driver and tightened to 10Ncm (Figure 10.74).

A hexed, implant temporary cylinder (IITCS41, Biomet 3i), previously coated with tooth-colored autopolymerizing acrylic resin, was placed into the implant in the maxillary left cuspid (Figure 10.75). A hexed cylinder was used

because the component had to go to place consistent with its location in the master cast. The try-in screw was hand tightened because it was to be removed after the clinical pick-up procedures were accomplished. The authors have found that placing autopolymerizing acrylic resin around temporary cylinders in the dry environment of the dental laboratory ensures better adhesion between the implant temporary cylinder and the provisional prosthesis during the clinical pick-up procedures.

Clinically, QuickBridge PEEK caps were pressed into place onto each QuickBridge titanium temporary cylinder



Figure 10.75. Clinical image of the hexed implant temporary cylinder in place in the maxillary left cuspid implant. Autopolymerizing acrylic resin had been added to the cylinder in the laboratory and allowed to set. The upper left inset is a hexed implant temporary cylinder and hexed try-in screw as received from the manufacturer.



Figure 10.76. Illustration of QuickBridge prosthetic components. The PEEK cap about to be placed onto a conical abutment (left); the QuickBridge PEEK cap in place on the titanium cylinder (right). These components are retained together with a press, frictional fit.



Figure 10.77. Laboratory illustrations of the treatment performed for the patient in this chapter. The image on the far left illustrates casts with maxillary conical abutments in place. The center image illustrates the same model with QuickBridge titanium cylinders in place. The image on the far right illustrates QuickBridge PEEK caps in place on the conical abutments/titanium cylinders. In this illustration, the two cuspid implants were to be restored with screw-retained implant temporary cylinders.

(Figures 10.76 and 10.77). The provisional prosthesis was seated onto the right cuspid implant with a try-in screw. The prosthesis was adjusted so that it did not touch any of the PEEK caps or temporary cylinder in place on the other implants (Figure 10.78).

INSERTION OF PROVISIONAL PROSTHESIS

An initial mix of autopolymerizing acrylic resin (Jet Acrylic, Land Dental Manufacturing Co.) was mixed and placed into the space associated with the maxillary left cuspid

implant. The prosthesis was screwed into the maxillary right cuspid implant, and the patient was guided into centric occlusion. Once the resin polymerized, the prosthesis was removed and the excess resin was removed from the intaglio surface of the provisional prosthesis in the area of the maxillary left cuspid implant.

Autopolymerizing acrylic resin (Jet Acrylic) was mixed in two batches. The first batch was injected into the areas of the prosthesis surrounding each conical abutment/QuickBridge component; the second batch was injected



Figure 10.78. Illustration of the treatment featured in Figure 10.77 where a laboratory-processed provisional prosthesis is about to be seated clinically onto QuickBridge prosthetic components. This illustration is similar to the treatment rendered in Chapter 10.



Figure 10.80. Laboratory image of implant and abutment analogs in place on the implant restorative components within the prosthesis. The machined implant restorative platforms were therefore protected from damage during the finishing and polishing procedures.



Figure 10.79. Clinical anterior image of the patient in centric occlusion. This image was taken immediately after the provisional prosthesis was relined with autopolymerizing acrylic resin. Two abutment try-in screws were placed into the implant temporary cylinders in the cuspid implant sites to retain the prosthesis in the predetermined three-dimensional position. The try-in screw (IUNITS, Biomet 3i; upper left inset).

intraorally into and around the retentive areas of the QuickBridge titanium and PEEK cylinders. The prosthesis was screwed into the two cuspid area implants with try-in screws (IUNIHT) and hand tightened. The patient was guided into centric occlusion, and the resin was allowed to polymerize (Figure 10.79).

The abutment screws were loosened and removed along with the prosthesis. This required some measure of vertical force as the QuickBridge PEEK caps had horizontal retention grooves that snapped into the grooves on



Figure 10.81. Laboratory image of the facial and intaglio surfaces of the provisional prosthesis after the finishing and polishing procedures were accomplished. Custom emergence profiles were made from acrylic resin in and around the implant temporary cylinders in the cuspid sites. The implant temporary cylinder on the patient's right side was nonhexed. The implant temporary cylinder on the patient's left side was hexed.

the QuickBridge titanium cylinders. Implant and abutment analogs were placed onto the implant restorative components and were tightened with laboratory screws (Figure 10.80).

Additional acrylic resin was added for optimal emergence profiles. The prosthesis was finished and polished (Figure 10.81).

TABLE 10.2. Properties of Dycal Radiopaque Calcium Hydroxide Composition

Feature	Benefit
Proven clinical efficacy	Shown to protect the pulp and promote the formation of secondary dentin
Fast setting	Saves time
High early strength	Strong at critical time after seating
Low water solubility	Less vulnerable to oral fluids for optimal long-term results
Available in dentin or ivory shade	Choice of the traditional appearance in ivory or dentin shade allows for natural-looking aesthetic restorations
Excellent handling characteristics	Easy to place, with ability to flow where needed; it stays in place when required



Figure 10.82. Clinical occlusal intraoral image of the provisional prosthesis in place after cementation and tightening of the abutment screws to 20Ncm. The screw access openings relative to the implant temporary cylinders were blocked out with cotton prior to restoring them with light-cured composite resin. Definitive abutment screws should not be used in the dental laboratory as the 24-karat gold coating will be removed with repeated insertions and removals. The beneficial properties associated with the gold coating would be negated. IUNIHG (upper left inset).

Temporary cement (Dycal® Radiopaque Calcium Hydroxide Composition, Dentsply International) was mixed and placed onto the internal surfaces of the QuickBridge PEEK caps (Table 10.2); the prosthesis was seated onto the QuickBridge titanium cylinders. Abutment screws (IUNIHG, Biomet 3i) were placed into the implant temporary cylinders in the prosthesis and torqued to 20Ncm with a torque instrument. The access openings were restored with cotton and light-cured composite resin (Figures 10.82–10.85).



Figure 10.83. Anterior clinical image of the provisional prosthesis in place. The prosthesis was contoured such that oral hygiene procedures could be accomplished with ease. The small space between the intaglio surface of the prosthesis and the peri-implant soft tissues did not affect phonetics or aesthetics.



Figure 10.84. Right buccal clinical image of the provisional prosthesis in place. The prosthesis was contoured so that oral hygiene procedures could be accomplished with relative ease. The spaces between the intaglio surface of the prosthesis and the peri-implant soft tissues did not affect phonetics or aesthetics.



Figure 10.85. Left buccal clinical image of the provisional prosthesis in place. The prosthesis was contoured so that oral hygiene procedures could be accomplished with relative ease. The spaces between the intaglio surface of the prosthesis and the peri-implant soft tissues did not affect phonetics or aesthetics.



Figure 10.86. Anterior clinical image of the provisional prosthesis in place at the 72-hour postoperative visit. The patient reported that he was comfortable and did not experience any pain since the combined surgical and prosthetic appointment 3 days prior.



Figure 10.87. Right buccal clinical image of the provisional prosthesis in place at the 72-hour postoperative visit. The patient was able to use SuperFloss® (Oral B®, Proctor & Gamble, Cincinnati, OH) to clean the intaglio surface of the provisional prosthesis.



Figure 10.88. Left buccal clinical image of the provisional prosthesis in place at the 72-hour postoperative visit. The patient reported that there had been minimal swelling secondary to the procedures, which was consistent with other reports from patients treated with a flapless surgical protocol, implant placement, and immediate occlusal loading.

Excess cement was removed with a periodontal scaler.

The patient was given postoperative instructions that included nonsteroidal anti-inflammatory medications and recommendations for a soft diet. Oral hygiene instructions were deferred until the 24-hour postoperative visit. The patient was extremely pleased with the aesthetic results and was discharged in excellent condition.

POSTOPERATIVE VISIT

The patient returned in 3 days for the first postoperative visit (Figure 10.86). He and his spouse were extremely pleased with the aesthetic results, and he reported absolutely no postoperative discomfort. The occlusion was evaluated and found to be consistent with the insertion appointment (Figures 10.87 and 10.88). Oral hygiene instructions were given, which included flossing demonstrations. He was discharged and asked to return in 1 month.

The following clinicians and dental laboratory technicians were responsible for the treatments illustrated in this chapter:

Clinician: Dr. Robert Del Castillo, Miami Lakes, FL

Dental Laboratory Technician: Alexey Zorin, North Shore Dental Laboratories, Lynn, MA

Illustrator: Robin deSomer Pierce, BSMT, Palm Beach Gardens, FL

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Chapter 11: Replacement of Denture Teeth and Denture Base for a Preexisting Mandibular Fixed/Detachable Prosthesis

INTRODUCTION

According to the Oral Health-Healthy People 2010: Objectives for Improving Health report, 26% of the US population between the ages of 65 and 74 years are edentulous (Healthy People 2010). Marcus and others (1996) estimated that there are at least 20 million Americans with edentulous mandibular jaws. Caplan and Weintraub (1993) reported that in the United States, whites have more teeth than do blacks of similar ages, and edentulism is more common among those with less education and income. Of those Americans aged 65+ years of age, over 40% are edentulous and only 2% percent have all 28 teeth. Doundoulakis and others (2003) reported that approximately one-third of Americans older than 65 years have at least one edentulous jaw and require replacement of missing teeth. Douglass and others (2002) have predicted that there will be approximately 38 million edentulous elderly adults in the United States by the year 2020.

While conventional complete dentures may meet the needs of many patients, other patients sometimes require more retention, stability, and function, especially in patients with edentulous mandibles. Implant-supported prostheses are an alternative to conventional removable dentures. Doundoulakis and others (2003) outlined the risks associated with this approach and performed a review of recent literature to summarize the reported survival rate of implants used to support mandibular overdentures. Their literature review indicated that endosseous implants placed into mandibles, anterior to the mental foramen, have a survival rate better than 95%, and patients have reported a high degree of satisfaction with implant-supported overdentures. They concluded that when clinicians develop treatment plans for patients with edentulous mandibles, they should consider implant-supported prostheses. Some patients may prefer fixed implant-retained prostheses, but the financial constraints for this treatment modality precluded their selection.

Fixed implant-retained prostheses provide numerous advantages to patients, including that the prostheses feel similar to their natural teeth, patients can bite with more force, and they no longer have to remove their prostheses during nighttime sleep (Liu 2005).

According to Adell and others (1981), osseointegration was defined as a firm, direct, and lasting connection between vital bone and screw-shaped titanium implants with a definitive finish and macroscopic geometry. They reported that there was no interposed tissue between fixtures and bone. They believed that osseointegration could only be achieved and maintained with a gentle surgical technique, long unloaded healing times, and proper stress distribution during function. Adell and others (1981) reported that during a 15-year period (1965–1980), 2,768 fixtures were placed into 410 edentulous jaws of 371 consecutive patients. All patients were provided with fixed/detachable prostheses and were examined at continuous yearly controls. The surgical and prosthetic protocols were developed and evaluated over a pilot period of 5 years. The results of the standardized procedures, applied on consecutive patients and with an observation time of 5–9 years, were thought to properly reflect the potential of the method. In this group, 130 jaws were provided with 895 fixtures, and of these, 81% of the maxillary and 91% of the mandibular fixtures remained stable, supporting the prostheses. In 89% of the maxillary and 100% of the mandibular cases, the prostheses were continuously stable. During healing and the first year after connection of the prostheses, the mean value for marginal bone loss was 1.5 mm. Thereafter, 0.1 mm was lost annually. The clinical results achieved with the fixed/detachable prostheses on osseointegrated fixtures fulfilled and exceeded the demands set by the 1978 Harvard Conference on successful dental implantation procedures.

Adell and others (1990) reviewed the long-term outcome of implant-retained prostheses and fixtures (implants) in 759 edentulous jaws of 700 patients. A total of 4,636 standard fixtures were placed and followed for a maximum of 24 years at the University of Göteborg. They utilized standardized, annual clinical and radiographic examinations, and a life table approach was applied for statistical analysis. Sufficient numbers of fixtures and prostheses for a detailed statistical analysis were present for observation times up to 15 years. More than 95% of the maxillary prostheses were stable at 5 and 10 years, and at least 92% were stable at 15 years. The figure for mandibular prostheses was 99% at all time intervals. Calculated from the time of fixture placement, the estimated survival rates for individual fixtures in maxillae were 84%, 89%, and 92% at



Figure 11.1. Laboratory occlusal view of a mandibular master cast with six implant analogs. Note the locations of the right and left distal implant analogs. Both of the analogs corresponded approximately to the positions of the second molars.



Figure 11.2. Panoramic radiograph of the patient in Figure 11.1 immediately post implant placement. Note the locations of the right and left distal implants. Both implants were placed into the second molar sites. Neither implant was placed completely into bone.

5 years; 81% and 82% at 10 years; and 78% at 15 years. In the mandible, they were 91%, 98%, and 99% at 5 years; 89% and 98% at 10 years; and 86% at 15 years. The different percentages at 5 and 10 years refer to results for different routine groups of fixtures with 1–5, 5–10, and 10–15 years of observation time, respectively. The results of this study concurred with other multicenter studies and earlier results for the Brånemark osseointegration method.

Authors have reported that the mandible undergoes significant dimensional changes during mastication (Goodkind and Heringlake 1972). The mandible is generally considered to be stable during mastication, without dimensional change between the mental foraminae. Distal to the foraminae, the mandible has been reported to exhibit considerable movement toward the midline on opening (Regli and Kelly 1967).

The most common anatomical positions for the mental foraminae are between the first and second mandibular premolars. Mandibular flexure should be considered when placing and splinting mandibular implants distal to the mental foramen. The more distal the splinting of mandibular implants occurs from one side to the other side with rigid frameworks, the greater the risk that mandibular flexure may influence the implants or prosthesis prognosis (Figures 11.1–11.3).

The mandible does not flex or exhibit significant torsion between the mental foraminae. Therefore, mandibular implants anterior to the mental foraminae may generally be splinted together without risk regarding mandibular flexure (Figures 11.4 and 11.5). The original Brånemark protocol called for placement of between four and six mandibular

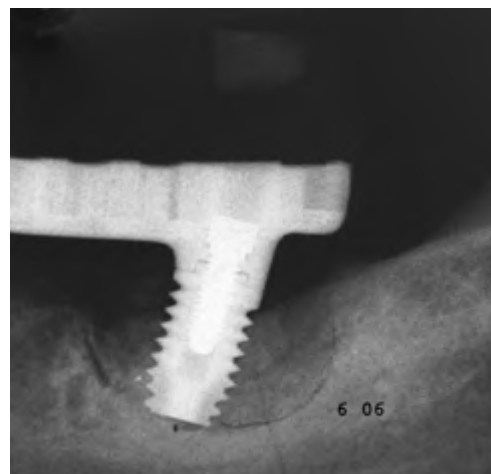


Figure 11.3. This radiograph was taken 3 years post loading. The patient complained of chronic discomfort in the left posterior mandibular area. The radiograph demonstrated a significant radiolucency around the left distal implant (outlined in pencil). The framework was removed, and the implant was extremely mobile. This implant probably was placed too far distal and with mandibular movements, significant forces were placed onto the implant and resulted in severe bone loss and loss of the implant. The prosthesis was sectioned distal to the next anterior implant in the left posterior quadrant and polished, and the patient was discharged without further incident or implant loss over the next 3 years.

implants between the mental foraminae with a two-stage surgical approach (Figure 11.6). After a 4- or 6-month healing period, the implants were uncovered and healing caps were placed (Figure 11.7). The definitive prostheses usually consisted of a maxillary complete denture and a mandibular fixed/detachable prosthesis (Figure 11.8).



Figure 11.4. Clinical anterior image of a patient with a maxillary complete denture and a mandibular fixed/detachable prosthesis 15 years post insertion. This patient experienced minimal wear of the prostheses, her oral hygiene was excellent, and she reported a positive experience with the prostheses.

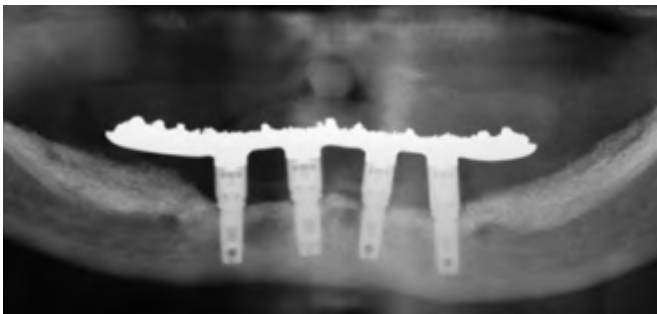


Figure 11.5. Panoramic radiograph of the patient in Figure 11.4. The radiograph demonstrated minimal bone loss around the implants. The patient originally presented to the authors after she had been grafted with hydroxyapatite granules in the mandible approximately 7 years previously. The graft was not successful in improving the patient's ability to wear a mandibular complete denture. The granules were removed in the anterior region prior to placement of the endosseous implants.

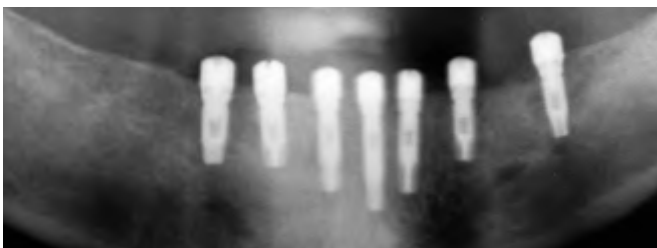


Figure 11.6. Panoramic radiograph of a patient immediately post placement of seven mandibular implants with a two-stage surgical protocol. The left and right distal implants were placed distal to the mental foramen.



Figure 11.7. Clinical occlusal view of the seven mandibular implants for the patient in Figure 11.6 immediately after the second surgical procedure that uncovered the implants.



Figure 11.8. Laboratory anterior image of the wax prostheses for the patient in Figures 11.6 and 11.7.

Implants have proven to be successful on a long-term basis. Osseointegration has provided edentulous patients with the means to regain near normal function on a long-term basis. However, the prosthetic materials are subject to wear and tear associated with mastication and parafunctional habits. The purpose of this chapter is to illustrate one prosthetic protocol to replace the acrylic resin teeth and denture bases associated with a maxillary complete denture and mandibular fixed/detachable implant-retained prosthesis, without replacing the cast metal framework.

CLINICAL PATIENT PRESENTATION

A 59-year-old female presented for a yearly recall appointment with a chief complaint, "My teeth are wearing down, and I can't see them when I smile" (Figure 11.9).



Figure 11.9. Clinical image of the patient illustrated in this chapter at rest, with her preexisting prostheses in place. These prostheses were inserted approximately 11 years prior to this photograph. Note the vertical lines within the upper lip and the lack of a visible vermilion border.

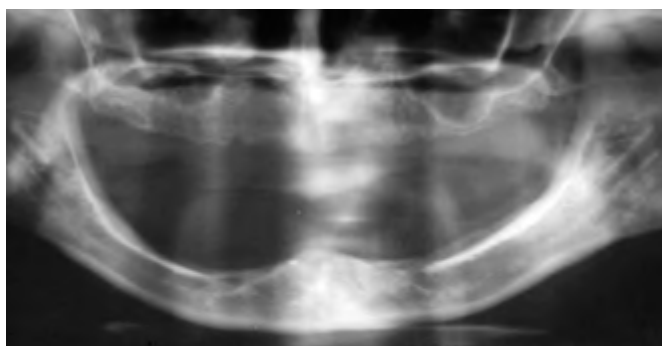


Figure 11.10. Initial panoramic radiograph that demonstrated moderate mandibular resorption in the anterior mandible and more significant resorption in the posterior mandibular quadrants.

This patient had been treated by the author approximately 11 years prior to this appointment with a maxillary complete denture and a mandibular fixed/detachable implant-retained prosthesis (Figures 11.10 and 11.11).

The physical examination revealed a decreased vertical dimension of occlusion (VDO) secondary to maxillary resorption and occlusal wear of the artificial teeth (Figures 11.12–11.15). The maxillary denture was unstable and exhibited minimal retention. There were no intraoral lesions or other soft tissue abnormalities.

DIAGNOSIS

The following diagnoses were established:

1. Decreased VDO secondary to occlusal wear of the maxillary and mandibular prostheses

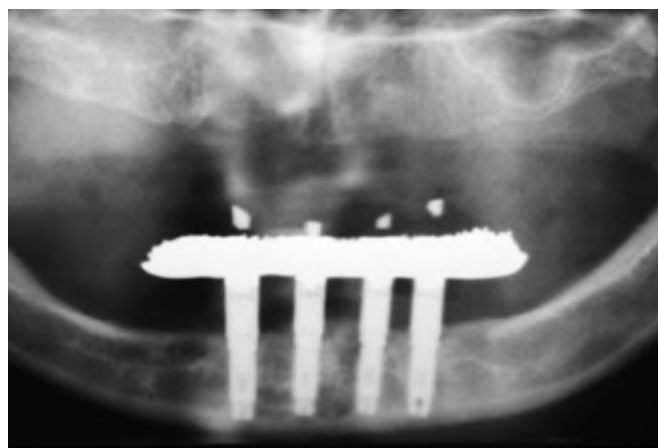


Figure 11.11. Panoramic radiograph approximately 1 year post occlusal loading of the mandibular implants. This radiograph demonstrated minimal bone loss around the endosseous implants.



Figure 11.12. Preoperative clinical anterior view with the patient in centric occlusion. The trans mucosal titanium alloy abutments were relatively polished and free of scratches. There was some plaque and other organic debris adherent to the prosthesis and the abutments. The peri-implant soft tissues were within normal limits.

2. Ill-fitting maxillary complete denture
3. Edentulous maxillae with moderate vertical and buccal/lingual resorption
4. Adequate bone volume for maxillary implant placement
5. Four osseointegrated implants in the anterior mandible
6. Negative medical history
7. Adequate salivary function
8. No intraoral pathology



Figure 11.13. Preoperative clinical right posterior view with the patient in centric occlusion. Note the significant wear and loss of anatomy of the posterior denture teeth.



Figure 11.15. Preoperative clinical occlusal view of the mandibular prosthesis. Note the significant wear and loss of anatomy of the denture teeth.



Figure 11.14. Preoperative clinical left posterior view with the patient in centric occlusion. Note the significant wear and loss of anatomy of the posterior denture teeth.

ASSESSMENT

The patient's chief complaint was valid in that the VDO was decreased secondary to occlusal abrasion of the denture teeth and continued bone resorption in her maxillae. The implants appeared to be osseointegrated and the preexisting framework appeared to be intact. If she desired any type of implant-supported prosthesis in the maxillae, she appeared to have enough bone to consider maxillary implants. If she did not wish to pursue maxillary implants, the treatment plan would consist of a new maxillary denture and replacement of the mandibular teeth and denture base. The preexisting framework, in all likelihood, could be reused.

The benefits and limitations of maxillary implants and maxillary implant-supported prosthesis versus a maxillary complete denture were discussed. After a thorough discussion, she expressed her understanding of the treatment options and decided to proceed with a new maxillary complete denture. Even though she reported a positive experience with the mandibular implant treatment, she felt that she would adapt to a new maxillary denture quite well and did not need the additional retention associated with maxillary implants. She was aware of the continued maxillary bone resorption that would occur without maxillary implants. She was also made aware that if in the future she desired maxillary implants, she might need to undergo bone grafting procedures prior to or in conjunction with implant placement.

The author felt comfortable in treating this patient's edentulous maxillae with a new complete denture. Successful accommodation of patients to complete dentures is not based solely on the adequacy of the prosthodontic treatment (Cooper 2009). Clinicians have reasoned that successful clinical management of edentulous patients has been correlated with technical procedures involved in constructing complete dentures. Recent data strongly suggest that patient-based measures of denture success may differ from those of clinicians (Ellis and others 2007).

APPOINTMENT SEQUENCE

In order to minimize the inconvenience to the patient regarding removal of the preexisting mandibular prosthesis during the treatment process, it was decided to schedule all of the patient's appointments in the following sequence:

1. Monday AM: Diagnostic alginate impressions of the edentulous maxillae, the preexisting maxillary complete denture, and of the mandibular prosthesis
 - a. Laboratory construction of a maxillary custom denture impression tray
2. Monday PM: Definitive maxillary impression in a custom impression tray of edentulous maxillae for the master cast
 - a. Laboratory construction of the maxillary master cast and maxillary record base and wax occlusion rim
3. Tuesday AM: Initial jaw relation records to determine the tentative vertical dimension of occlusion, and tooth selection for the maxillary complete denture
 - a. Laboratory mounting of the maxillary and mandibular casts
4. Tuesday PM: Wax try-in of the wax maxillary denture and removal of the mandibular implant-retained prosthesis; evaluate the usability of the preexisting standard abutments and implants; retorque the abutment screws to 20Ncm; place healing caps onto the standard abutments
 - a. Laboratory placement of new abutment analogs onto the restorative platforms of the preexisting mandibular prosthesis and make a mandibular cast
 - b. Remove the denture base and denture teeth from the preexisting mandibular prosthesis; set the maxillary and mandibular denture teeth onto the maxillary record base and mandibular cast metal framework
5. Wednesday AM: Wax try-in #2 with a wax maxillary complete denture and new teeth on the preexisting mandibular implant-retained framework; evaluate the vertical dimension of occlusion, lip support, incisal display, and jaw relation record
 - a. Remount; reset the teeth as needed; complete waxing, invest, boil out, process, and finish the prostheses
6. Thursday PM: Remove healing caps from the mandibular abutments; place the mandibular implant-retained prosthesis with new retaining screws; restore the screw access openings; insert the new maxillary complete denture; evaluate and adjust the prostheses as needed
7. Friday PM: 24-hour postinsertion visit to evaluate the occlusion, soft tissue response, and patient adaptation to the new prostheses

This appointment sequence minimized the amount of time the patient would be inconvenienced by going without the mandibular prosthesis (4 days); more significantly, it also spared her the expense of making a new implant-retained

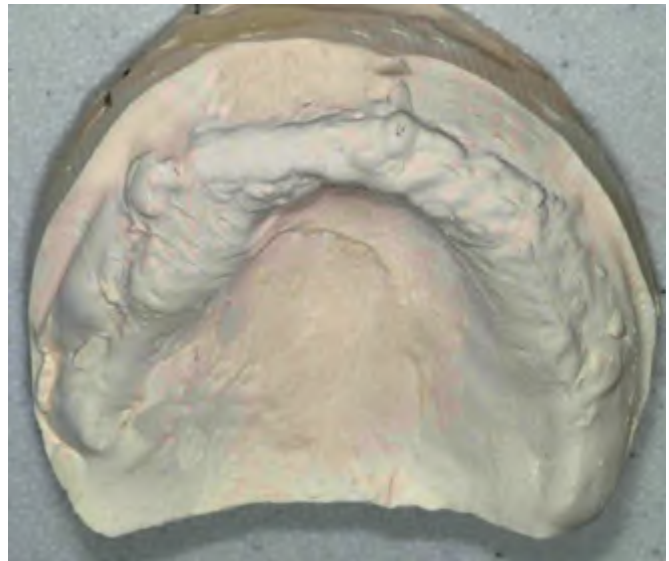


Figure 11.16. Laboratory occlusal view of the maxillary diagnostic cast. This cast was used to fabricate a custom impression tray prior to the definitive impression for the maxillary complete denture. There has been considerable resorption in the anterior maxillae.

framework. This treatment sequence was possible to accomplish in a short period of time because the author had an in-house dental laboratory technician, and the treatment was scheduled consistent with the schedules of the patient, clinician, and dental laboratory technician.

This protocol would not work for all patients and restorative dentists, especially if a patient would not tolerate being without the mandibular implant-supported prosthesis.

DIAGNOSTIC CASTS

Diagnostic casts are accurate reproductions of all of the clinical features of dentulous or edentulous jaws. These include teeth; contours; occlusal plane location; residual ridge contour and size; and the oral anatomy that defines the extensions of removable prostheses such as vestibules, retromolar pads, pterygomaxillary notches, hard and/or soft palatal junction, floor of the mouth, and location and extent of frena. Once diagnostic casts have been mounted, the location and orientation of the occlusal plane, and tooth/ridge relationships (vertical and horizontal) can be much better visualized by clinicians and dental laboratory technicians. Record bases are needed in order to mount edentulous or some partially edentulous casts.

Diagnostic casts are usually made with dental stone, instead of plaster, due to its greater strength and abrasion resistance (Figures 11.16 and 11.17).



Figure 11.17. Laboratory lateral occlusal view of the mandibular diagnostic cast. This cast was mounted against the maxillary record base and occlusion rim after the initial jaw relation records were obtained.

CUSTOM MAXILLARY IMPRESSION TRAY AND DEFINITIVE MAXILLARY IMPRESSION

Treatment of edentulous patients with complete dentures is a technically demanding task. Definitive impressions are one of the most critical steps clinicians perform in the process of fabricating complete dentures (Felton and others 1996; Zarb and others 1997). The objective of the complete denture definitive impression is to accurately record the entire denture-bearing area to produce a stable and retentive prosthesis while maintaining patient comfort, aesthetics, and preservation of the remaining tissues (Chaffee and others 1999).

The majority of US dental schools teach complete denture definitive impression techniques consisting of secondary impressions in border-molded custom impression trays (Arbree and others 1998). Even though the materials used in definitive denture impressions varied among the reporting dental schools, the techniques were remarkably similar. However, a significant number of dentists reported that they abandoned the procedures that were taught in the complete denture curriculum and made definitive denture impressions in their private practices with techniques they regarded as simpler (Gauthier and others 1992). Definitive impressions for complete dentures have been reported to be one of the more critical elements in complete denture prosthodontics (Klein and Broner 1985). The main objective in definitive impressions is for clinicians to obtain accurate impressions of the denture-bearing areas of the edentulous jaws (Duncan and Taylor 2001). Accurate impressions are important in fabricating stable and retentive prostheses with optimal aesthetics, function, and a comfortable fit for edentulous patients.

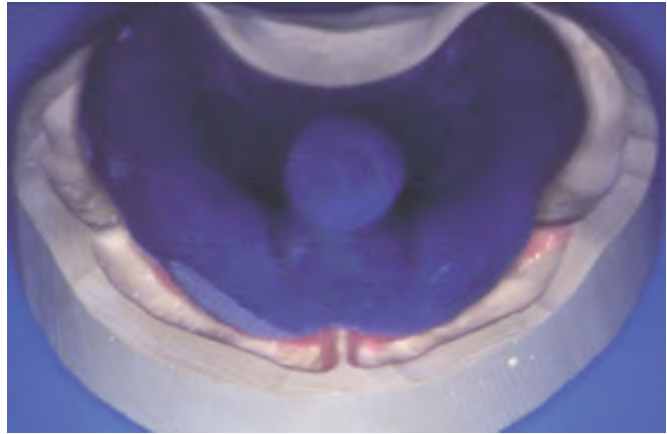


Figure 11.18. The custom maxillary impression tray was made directly on the surface of the maxillary diagnostic cast. No spacer was used.

Definitive denture impressions may be made with various materials: impression plaster, zinc-oxide/eugenol, polysulfide rubber, irreversible hydrocolloid, polyvinyl siloxane, or polyether (Zarb and others 1997). The techniques for definitive denture impressions can be divided into four classes: mucostatic (Page 1951), maximum displacement (Fournet and Tuller 1936), functional (Vig 1964), and selective pressure (Heartwell and Rahn 1986). Variations in these fundamental concepts have been described by numerous authors (Klein and Broner 1985; Heartwell and Rahn 1986; Winkler 1988; Zarb and others 1997). It has been acknowledged that a single technique cannot be used for all clinical situations (Felton and others 1996; Zarb and others 1997). Chaffee and others (1999) published a definitive denture impression protocol that illustrated the use of a selective pressure placement technique. Polyvinyl siloxane impression material was used to border mold custom impression trays. The authors believed that using this material to border mold denture impressions and using the selective pressure placement impression technique, predictable results could be achieved in making properly extended, accurate definitive impressions.

Impression trays must be sufficiently rigid to prevent distortion during impressions and cast-forming procedures. They should fit the mouth with a uniform amount of clearance, consistent with the type of impression material to be used. To minimize chairtime for clinicians, custom impression trays need to be trimmed 1–2mm short of the vestibular reflections on the diagnostic casts. The definitive borders of the impression trays will be reestablished with a border molding material that takes into account patients' functional movements.

In this case, the maxillary custom impression tray was made directly on the surface of the maxillary diagnostic cast, without any type of spacer (Figure 11.18). It was felt

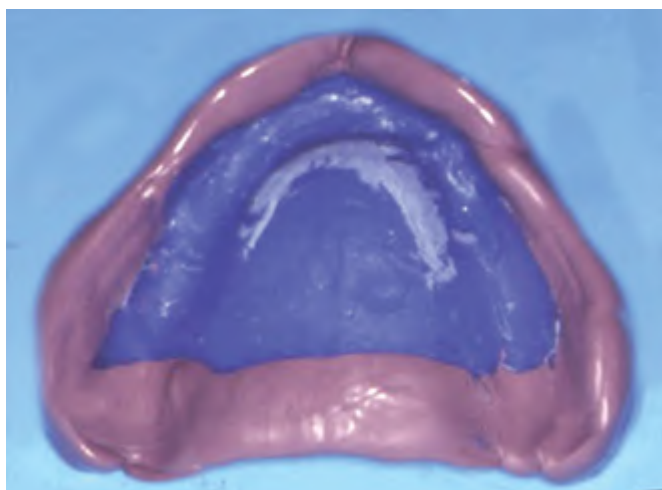


Figure 11.19. The impression tray was border molded with heavy-body polyvinyl siloxane impression material.

that pressure could be placed more accurately through the impression tray directly onto the posterior ridges without having a spacer applied to the cast prior to construction of the tray. The impression tray was made from visible light-cured resin, following the manufacturer's instructions. (Triad®, Dentsply International, York, PA). Perforations were not placed into the maxillary impression tray so that retention of the impression tray could be evaluated after the peripheral border molding was completed.

Prior to border molding, adhesive (Tray Adhesive, 3M Dental Products, St. Paul, MN) was placed onto the borders of the maxillary impression tray and allowed to dry. Heavy-body polyvinyl siloxane impression material (Extrude®, Kerr USA, Romulus, MI) was applied to the entire border of the impression tray, and border molding of the maxillary tray was accomplished. If the border molding is incomplete, adhesive may be reapplied to the tray and impression material, and additional heavy-body impression material may be placed onto the borders to complete the process. The border-molded impression tray was stable and retentive with one application of the heavy-body impression material. Prior to the definitive impression, the patient was asked to rinse with a nonalcoholic mouthrinse, and the mouth was dried with gauze. Tray adhesive (Tray Adhesive) was applied to the entire intaglio surface, including the borders, of the impression tray, and the definitive impression was made with light-body polyvinyl siloxane impression material (Extrude). Salinas (2009) has recommended that high-flow impression materials be used for edentulous maxillae and that high-viscosity materials should be used for mandibular edentulous impressions. Once the material set, the impression was removed and inspected for voids (Figures 11.19 and 11.20) (Drago 2003).

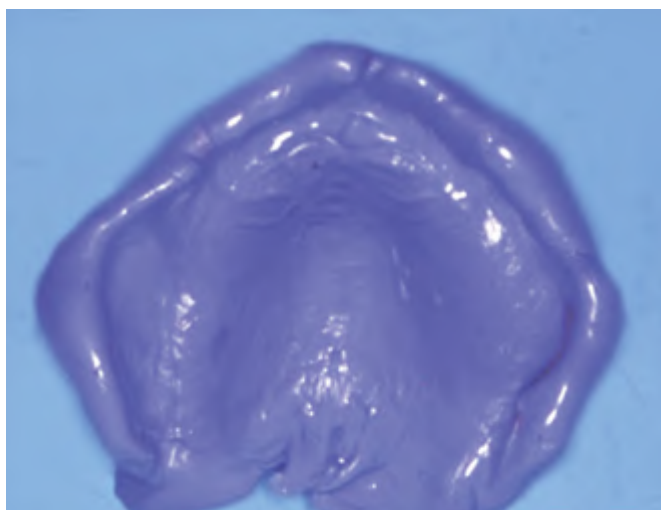


Figure 11.20. This is the intaglio surface of the definitive impression.

The impression was boxed and poured in dental stone, per the manufacturer's instructions.

MAXILLARY MASTER CAST

The principal problems associated with master casts generally involve incorrect water/powder ratios. Inaccurate ratios can result in markedly inferior, soft casts of inadequate strength. Numerous voids within a cast are generally caused by inadequate spatulation of the stone/water mixture and not using vacuum spatulation. One final problem often seen in master casts involves a rough surface from slurry splatter. The remedy for the latter issue is to dip the casts in clear slurry water before trimming on cast trimmers and repeat frequently during the trimming process.

The maxillary cast was trimmed and made ready for fabrication of the record base and occlusion rim (Figure 11.21).

MAXILLARY RECORD BASE AND WAX OCCLUSION RIM

Keyworth (1929) published a paper several decades ago on complete denture prosthodontics and reported that record bases were designed to do the following:

1. Act as carriers for occlusion rims
2. Hold the teeth in the wax setup for the wax try-in
3. Check the accuracy of the initial jaw relation records

Dentists use record bases and occlusion rims to transfer key clinical information to dental laboratory technicians: skeletal/dental jaw relationships (Figures 11.22–11.26);

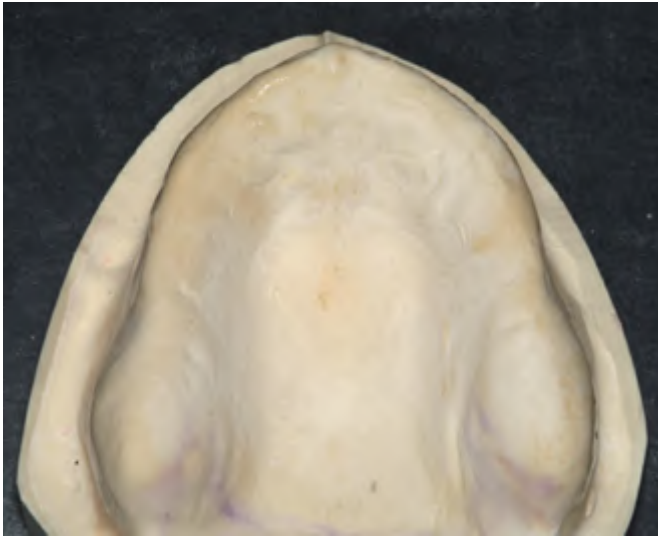


Figure 11.21. Laboratory occlusal image of the maxillary master cast.

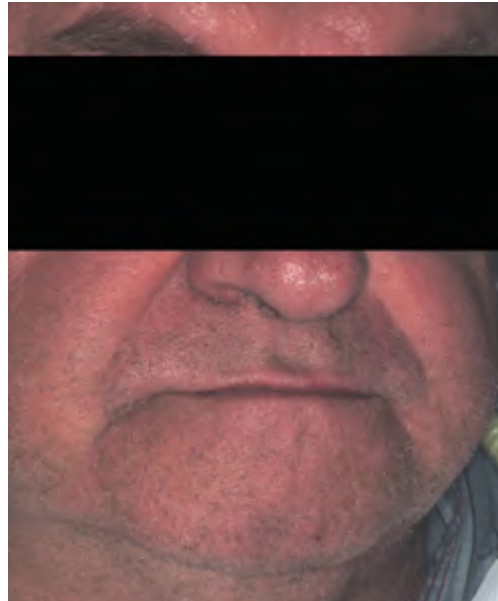


Figure 11.22. Preoperative clinical image of a patient who had been edentulous for over 25 years. In this photograph, he was wearing the original maxillary and mandibular complete dentures. The vertical dimension of occlusion was decreased, there was inadequate lip support, and he appeared to have a Class III skeletal malocclusion.



Figure 11.23. Lateral clinical image of the patient in Figure 11.22 with the original dentures in place. The maxillae are retrognathic relative to the mandible. This is consistent with the overall resorption patterns of edentulous maxillae and mandibles in that maxillae resorb upward and backward and mandibles resorb down and forward.



Figure 11.24. This is the intraoral image of the patient in Figures 11.22 and 11.23 with the dentures in centric occlusion. The dentures were now in a Class III dental malocclusion, consistent with the skeletal resorptive pattern of edentulous jaws.

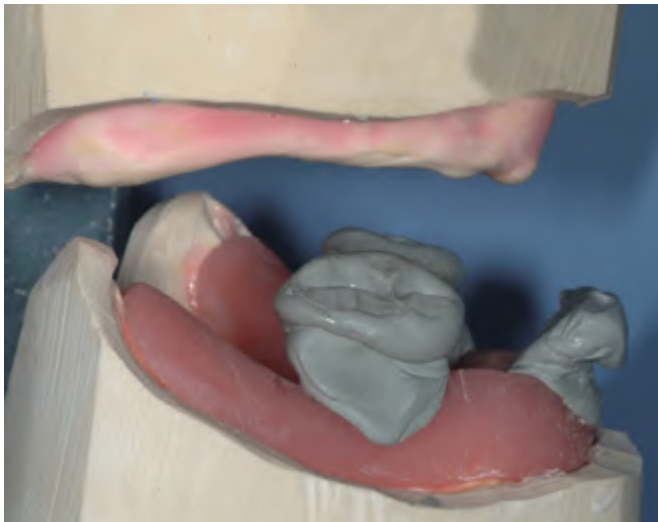


Figure 11.25. This is the laboratory lateral image of the articulator mounting of the edentulous casts of the patient in Figures 11.22–11.24 with the mandibular record base in place. The planned locations for the new mandibular anterior teeth were identified by the gray modeling compound anterior stop. There was a marked Class III skeletal relationship present between the maxillary and mandibular jaws.



Figure 11.26. This is the laboratory lateral image of the articulator mounting of the edentulous casts of the patient in Figures 11.22–11.25 that demonstrated a less severe skeletal Class III malocclusion between the edentulous jaws. The mandibular record base was removed.



Figure 11.27. This is a clinical image of a patient smiling with dentures that were 20 years old. None of the mandibular teeth were visible.



Figure 11.28. This is a clinical image of the patient in Figure 11.27 smiling, with the wax dentures in place, at the try-in appointment. The vertical dimension of occlusion had been increased, the maxillary anterior teeth were moved labially, and the mandibular anterior teeth were moved superiorly to provide increased lip support and better aesthetics.

dental midline; location of the occlusal/incisal planes; location of the anterior gingival margins; location of the maxillary cuspid teeth; amount of vertical and horizontal overlap and lip support; and the location of the posterior teeth relative to the buccal corridors (Figures 11.27 and 11.28).

Elder (1955) established the following requirements for record bases. They should:

1. Adapt to the basal seat areas as well as the definitive denture bases



Figure 11.29. Laboratory view of the intaglio surface of the maxillary record base.

2. Have the same peripheral border form as the definitive denture bases
3. Be rigid
4. Be dimensionally stable
5. Permit their use as bases for setting denture teeth
6. Be easy and inexpensive to fabricate
7. Be of an eye-pleasing color

This maxillary record base was fabricated from visible light-cured resin, per the manufacturer's instructions (Triad) (Figure 11.29).

The majority of occlusion rims are made with baseplate wax. The main purpose of a wax occlusion rim is to permit the transfer of clinical information from the patient to the dental laboratory technician, as outlined above. Maxillary occlusion rims are generally made with the following initial dimensions:

1. Twenty-two-millimeter-long when measured from the highest part of the peripheral border to the incisal edge of the occlusion rim; this is generally in the cuspid area
2. The posterior height of a maxillary occlusion rim should be approximately 6–8mm when measured from the tissue surface of the maxillary record base to the occlusal surface of the occlusion rim
3. The facial incisal edge of a maxillary wax occlusion rim should be approximately 7–8mm anterior to the center of the concavity formed by the incisive papilla
4. The buccal/lingual width of the maxillary occlusion rim should be approximately 8mm

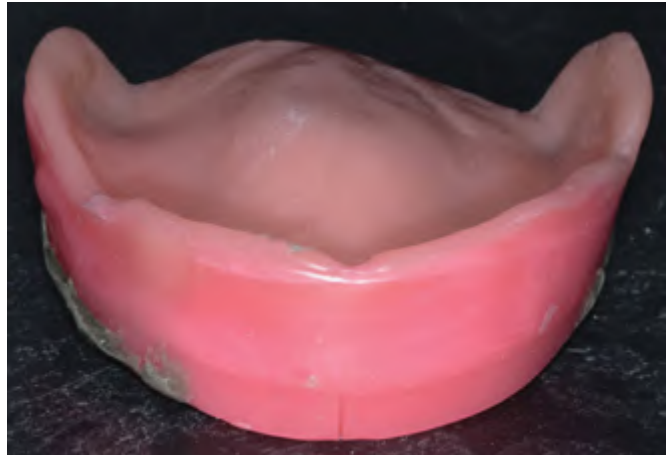


Figure 11.30. Laboratory view of the facial surface of the maxillary record base and occlusion rim.

5. The curvature of the maxillary occlusion rim should correspond to the overall curvature of the edentulous maxillae (Figure 11.30)

CLINICAL JAW RELATION RECORDS

The clinical appointment for accurately establishing jaw relationships is sometimes overlooked by clinicians (Phoenix and others 2003). It is absolutely essential that the jaw relation record be accurate relative to occlusal vertical dimension and the centric jaw relationships. The goal in developing an occlusal scheme in implant prosthodontics is to establish and maintain a harmonious relationship with the oral structures/implants and to provide mastication that is efficient and aesthetically acceptable. Occlusal harmony must be present in centric occlusion/relation and all eccentric positions.

Vertical dimension refers to a vertical measurement of the face and jaws between two arbitrary points—one above and one below the lips. One vertical dimension of rest (VDR) is defined as the vertical dimension between the two jaws with the patient's head upright and unsupported by a headrest, and with the lips just touching. This dimension is not constant. Recording the VDR is part of the art and science of prosthodontics (Rugh and Drago 1981). For convenience, two dots may be placed onto the patient's face—one on the nose and one on the chin. In this case, the patient was asked to wet her lips and slowly close her mouth until her lips touched. This was taken as the VDR (Figure 11.31). Arbitrarily, 3mm was subtracted from this measurement for the initial VDO.

The maxillary occlusal plane, lip support of the upper lip, and the amount of incisal display at rest, speaking, and



Figure 11.31. Lateral clinical profile of the patient, with the maxillary record base and occlusion rim in place, after the labial surfaces had been contoured for optimal lip support. The patient was asked to wet her lips and close her mouth until her lips touched. This was recorded as the vertical dimension of rest position. Three millimeters were arbitrarily subtracted from this measurement to obtain the preliminary vertical dimension of occlusion.

smiling were initially established with the maxillary record base and occlusal rim. The initial VDO was established by using the anterior teeth of the preexisting prosthesis as the anterior stop on the mandibular record base. The author realized that since the preexisting worn, mandibular prosthesis was still in place, this was not going to be the definitive VDO measurement. Once this was established, two posterior stops were made on the posterior segments of the maxillary occlusion rim with wax (Aluwax™, Aluwax Dental Products Co., Allendale, MI) and the actual jaw relation record was made. Per the manufacturer's Web site (www.aluwaxdental.com), Aluwax dental wax is a composite material that contains powdered aluminum. Powdered aluminum increases the integrity of the compound and provides heat retention properties required for efficient modeling. Other materials, such as copper-based waxes, do not retain heat as long and begin to harden quicker than clinicians may want. The midline was marked on the maxillary occlusion rim, and a tooth form and shade were selected. The patient was discharged to return for the initial wax try-in (Figure 11.32).

FIRST ARTICULATOR MOUNTING

The jaw relation record was used to orient the casts for mounting in an articulator. In some instances, facebow records may be used for mounting maxillary casts



Figure 11.32. Laboratory occlusal view of the maxillary record base and occlusion rim after the jaw relation record was made in wax.

(Weinberg 1961). With the previous technique, once the maxillary cast has been mounted with the facebow record, the mandibular cast is oriented to it with an interocclusal record and mounted as well.

Casts may also be mounted without facebow records. With a nonfacebow protocol, the casts are positioned into an articulator arbitrarily and attached to the upper and lower members of the articulator with stone. Mounting stone is preferred to dental stone or plaster of paris due to its lower setting expansion.

In this case, the casts were mounted arbitrarily in the articulator with the occlusal plane horizontal, the maxillary midline centered, and the casts in the middle of the simple hinge articulator (Figures 11.33–11.35). The casts were mounted with mounting stone (Whip Mix Corp., Louisville, KY) mixed according to the manufacturer's instructions. The casts were mounted at the recorded VDO, in spite of the fact that it only took into account the location of the maxillary occlusal plane.

MAXILLARY WAX DENTURE

Denture teeth may be made from porcelain, acrylic resin, composite resin, and resin/metal combinations. All of the different types of teeth have advantages and disadvantages. The authors prefer to use acrylic resin denture teeth because of their versatility, availability, reasonable durability, and aesthetics. Anterior teeth may be selected consistent with the patient's natural teeth or they may be changed per the patient wishes. This holds true for both color



Figure 11.33. Anterior laboratory view of the casts mounted in the simple hinge articulator. The maxillary midline was centered medial/laterally, consistent with the incisal guide pin. The occlusal plane was placed in the middle of the upper and lower members of the articulator, parallel to the horizontal plane. The mandibular cast was mounted to the maxillary cast. All of the mountings were made with mounting stone.



Figure 11.35. Left buccal laboratory view of the casts mounted in the articulator. The casts were mounted so that the occlusal plane was horizontal and in the middle of the upper and lower members of the articulator.



Figure 11.34. Right buccal laboratory view of the casts mounted in the articulator. The casts were mounted so that the occlusal plane was horizontal and in the middle of the upper and lower members of the articulator.

and mold. In complete denture prosthodontics, the author prefers to let patients select their own shades. Mold selection is based upon three factors: aesthetics, space, and size. Perhaps the most important factor is related to the space that has been created by tooth loss. In edentulous cases, it is important to remember that the artificial teeth need to be placed where the natural teeth were, and not

in relation to the present shape and location of the residual ridge.

Under some circumstances, patients may wish to change their basic tooth shape and ask the dentist for assistance. There are numerous techniques available to accomplish this. The readers are referred to textbooks on complete denture prosthodontics for further information.

The third factor in mold selection is the overall shape of the teeth. Teeth are generally divided into four basic forms: square, tapering, square tapering, and ovoid. Tooth shapes may be correlated with facial forms. Again, clinicians generally use their experience to select teeth appropriate for a given patient. In this case, the anterior teeth selected were Justi Blend® acrylic resin teeth; the posterior teeth were 20-degree Anatomical Justi Blend® (Justi Products, Oxnard, CA).

The teeth were set consistent with the contours of the maxillary occlusion rim and were set on the record bases for the wax try-in. Twenty-degree teeth were used in the posterior segments. These teeth were set for optimal centric contacts and group function occlusion in right and left working movements (Figures 11.36–11.39).

The patient, her spouse, and the author evaluated the aesthetics, lip support, occlusal vertical dimension, and rest vertical dimension of the maxillary wax denture at the wax try-in appointment. The author evaluated the accuracy of the jaw relation record per the above parameters.



Figure 11.36. Laboratory anterior view of the maxillary wax denture in the articulator, ready for try-in. The initial wax try-in was done with a cast of the preexisting mandibular prosthesis as the prosthesis had not yet been removed.



Figure 11.38. Laboratory left buccal view of the maxillary wax denture in the articulator, ready for try-in. At this time, the posterior teeth were set for maximum intercuspation. The initial wax try-in was done with a cast of the preexisting mandibular prosthesis as the prosthesis had not yet been removed.



Figure 11.37. Laboratory right buccal view of the maxillary wax denture in the articulator, ready for try-in. At this time, the posterior teeth were set for maximum intercuspation. The initial wax try-in was done with a cast of the preexisting mandibular prosthesis as the prosthesis had not yet been removed.

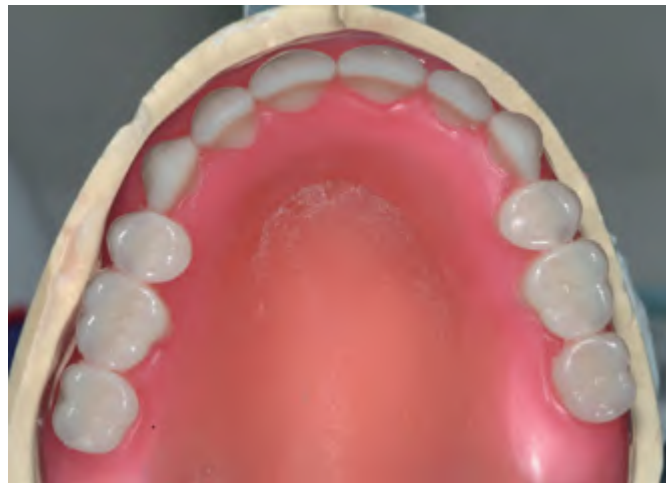


Figure 11.39. Laboratory occlusal view of the maxillary wax denture.

The patient and her spouse agreed to the aesthetics of the maxillary wax denture. A new centric jaw relation record was made with polyvinyl siloxane recording material so that the mandibular prosthesis could be mounted against the maxillary wax denture in the articulator.

The mandibular prosthesis was removed by removing the screw access restorations, cotton block out material, and the retaining screws. Healing caps were placed onto the standard abutments to protect the patient's tongue from the sharp line angles of the abutments (Figures 11.40 and 11.41).



Figure 11.40. Clinical intraoral facial view of the healing caps (TS250, Biomet 3i; inset) in place on the preexisting standard abutments (AB550, Biomet 3i). The caps protected the tongue from the sharp line angles of the standard abutments.



Figure 11.41. Clinical intraoral occlusal view of the healing caps (TS250; inset) in place on the preexisting standard abutments (AB550). The caps protected the tongue from the sharp line angles of the standard abutments.



Figure 11.42. Laboratory occlusal view of the preexisting mandibular fixed/detachable prosthesis after it was removed from the mouth.

MANDIBULAR MASTER CAST

This prosthesis was originally designed with long (4- and 5.5-mm transmucosal standard abutments) abutments. Consequently, there were large amounts of space between the intaglio surface of the prosthesis and the peri-implant soft tissues. Therefore, an impression that recorded the relationship between the intaglio surface of the prosthesis and the soft tissues was not needed as the preexisting framework was designed as a hybrid prosthesis without soft tissue contact. The casting had also been designed and cast with buccal and facial finish lines.

In order to save the patient the additional expense associated with removing the preexisting abutments and making an implant-level impression for a second implant-retained framework, it was decided to use the implant-retained prosthesis to make the mandibular master cast (Figure 11.42). After the prosthesis was removed from the implants,



Figure 11.43. Laboratory left lateral view of the preexisting mandibular fixed/detachable prosthesis. Prior to pouring the cast, laboratory screws (WSK15; right inset) were placed into the screw access openings and connected to abutment analogs (SLA20; left inset) on the intaglio surface of the prosthesis.



Figure 11.44. Laboratory intaglio view of the preexisting mandibular prosthesis with the abutment analogs in place on the restorative platforms of the metal casting in the prosthesis. Metal-to-metal contact was visualized around the peripheries of the analog/abutment interfaces.

four laboratory screws (WSK15, Biomet 3i, Palm Beach Gardens, FL) and abutment analogs (SLA20, Biomet 3i) were selected (Figure 11.43). It was not necessary to know the heights of the preexisting standard abutments; it was the abutment/analog connection that was critical to establish. The laboratory screws were placed into the screw access openings and screwed into the new abutment laboratory analogs (Figure 11.44).

In this case, type IV dental stone was vacuum mixed per the manufacturer's instruction and vibrated into a plastic mold used to make bases for dental casts. (GC Fujirock® EP, GC America Inc., Alsip, IL). The preexisting



Figure 11.45. Laboratory occlusal view of the preexisting mandibular fixed/detachable prosthesis in the mandibular cast. This cast, with the prosthesis, was ready to be mounted with the interocclusal record. Slotted try-in screws are in place.



Figure 11.46. Laboratory facial view of the preexisting mandibular fixed/detachable prosthesis in the mandibular cast. This cast and prosthesis were ready to be mounted with the interocclusal record. The framework was originally designed with the intaglio surface in metal and buccal/lingual finish lines. Therefore, the new cast was not made from an impression of the prosthesis in place. If the preexisting prosthesis was designed with an acrylic resin wraparound protocol, a pick-up impression would have been necessary, which would have created a cast in contact with the intaglio surface of the prosthesis.

framework, with the abutment analogs in place, was gently vibrated into the stone so that all of the analogs were embedded into the stone. The stone was allowed to set; the prosthesis was removed (Figures 11.45–11.48).

SECOND ARTICULATOR MOUNTING—MANDIBULAR MASTER CAST

The mandibular cast was luted to the maxillary wax denture with the interocclusal record in place (Figures 11.49 and



Figure 11.47. Laboratory lingual view of the preexisting mandibular fixed/detachable prosthesis in the mandibular cast. This cast and prosthesis were ready to be mounted with the interocclusal record.



Figure 11.48. Laboratory occlusal view of the mandibular master cast with the abutment analogs in place. The analogs were placed consistent with their corresponding intraoral positions as determined by the restorative platforms of the framework. Due to the presence of the standard abutments and the design of the metal framework in the preexisting prosthesis, the peri-implant soft tissue contours did not have to be recorded in the master cast.

11.50). The cast was mounted with mounting stone (Whip Mix Corp.) mixed according to the manufacturer's instructions.

MANDIBULAR WAX DENTURE

Since the jaw relation record was made with the maxillary wax denture opposed by the preexisting mandibular prosthesis, the VDO was not recorded at the correct vertical dimension. The VDO had to be increased an arbitrary amount in the laboratory so that some of the mandibular incisal edges would be visible as verbalized in the patient's original chief complaint. The incisal guide pin was raised approximately 2.5mm on the incisal guide table (Figures 11.51–11.53).



Figure 11.49. Laboratory anterior view prior to mounting the mandibular cast in the articulator. (The articulator is upside down.) The interocclusal record was in place on the occlusal surfaces of the mandibular prosthesis and maxillary wax denture. The casts were luted together with tongue blades and gray modeling compound. Mounting stone was mixed per the manufacturer's instructions, and the mandibular cast was mounted.



Figure 11.50. Laboratory anterior view of the mandibular prosthesis and master cast mounted against the maxillary wax denture and maxillary master cast.



Figure 11.51. Laboratory anterior view of the mandibular prosthesis and master cast mounted against the maxillary wax denture and maxillary master cast. To compensate for the worn teeth on the preexisting mandibular prosthesis, the incisal guide pin was raised approximately 2.5 mm from the original mandibular cast position in the articulator mounting.



Figure 11.52. Right laboratory view of the mandibular prosthesis and master cast mounted against the maxillary wax denture and maxillary master cast. To compensate for the worn teeth on the preexisting mandibular prosthesis, the incisal guide pin was raised approximately 2.5 mm from the original mandibular cast position in the articulator mounting. There is approximately 1 mm of interocclusal clearance between the new maxillary denture teeth and the existing mandibular right posterior teeth.



Figure 11.53. Left laboratory view of the mandibular prosthesis and master cast mounted against the maxillary wax denture and maxillary master cast. To compensate for the worn teeth on the preexisting mandibular prosthesis, the incisal guide pin was raised approximately 2.5 mm from the mandibular position in the articulator mounting. Note the significant amount of interocclusal clearance between the new maxillary denture teeth and the preexisting mandibular posterior teeth.



Figure 11.55. Right laboratory view of the mandibular framework and master cast mounted against the maxillary wax denture and maxillary master cast. There was adequate interocclusal clearance between the right posterior segments to optimally position the maxillary and mandibular right posterior teeth.



Figure 11.54. Laboratory occlusal view of the preexisting framework after removal of the denture base and denture teeth.

All of the denture teeth and denture base acrylic resin were removed from the preexisting mandibular prosthesis by a combination of grinding, boiling water, and shell blasting (Figures 11.54–11.57).

SILICOATING

In prosthodontics, the attachment of a resin matrix to a metal framework may pose significant difficulties as there is no chemical bonding, only mechanical retention between



Figure 11.56. Left laboratory view of the mandibular framework and master cast mounted against the maxillary wax denture and maxillary master cast. There was adequate interocclusal clearance between the left posterior segments to optimally position the maxillary and mandibular left posterior teeth.

the two materials. The major problems are related to the strength of the attachment and the space available for restorative materials. Low attachment strength between the resin and metal framework may result in microleakage, discoloration, or breakage. Minimal space available for metal frameworks, resin matrix, and denture teeth may result in compromised tooth placement and a less than ideal bond between the prosthetic materials. Clinically, limited space and low bond strength may result in unacceptable aesthetics, a need for excessive adjustment of the



Figure 11.57. Lingual laboratory view of the mandibular framework and master cast mounted against the maxillary wax denture and maxillary master cast. There was adequate interocclusal clearance between the anterior segments to optimally position the maxillary and mandibular anterior teeth.



Figure 11.58. Clinical image of a missing denture tooth from a mandibular fixed/detachable prosthesis. The patient had a severe nocturnal bruxism habit and dislodged the denture tooth from this prosthesis during nighttime sleep. Note the significant amount of wear present on the other denture teeth in the prosthesis.

occlusion, or breakage of any of the materials (Figure 11.58). To minimize clinical problems, it is therefore imperative to optimize the strength of the resin attachment to the metal framework and ensure that there is sufficient room for dental materials.

Until recently, the attachments of resins to metal frameworks have been obtained through mechanical retention between the resin and the frameworks. Mechanical retention can be achieved using latticework, mesh, beads, and various posts (Henderson and Steffel 1981). Alternative attachment mechanisms are now available, including micromechanical and chemical attachment systems.



Figure 11.59. Laboratory occlusal view of the cast metal framework after silicoating. The silicoating served to improve the bond between the denture base acrylic resin and the metal framework, and it opaqued the framework to eliminate metal showing through the processed denture base acrylic resin. Slotted waxing screws retained the framework to the analogs in the master cast.

Micromechanical attachment can be accomplished using sandblasting, electrochemical etching, and chemical etching (Adept Institute 1991). Chemical attachment may be achieved using adhesive cements, porous metal coatings, silicoating (Hansson 1989), and the Kevloc system. These alternative attachment systems can be used either as an addition to or in place of conventional macromechanical retention.

There are numerous advantages to chemical resin/metal attachment systems:

1. Increased bond strength between resin and metal
2. Decreased microleakage at the resin/metal interface
3. Reduction in metal impingement on the space needed for the placement of denture base resin and teeth
4. Improved aesthetics because the metal frameworks have been opaqued and the thickness of resin has been increased

For the fixed/detachable implant prosthesis fabricated in this case, interarch space was not a concern. The preexisting macromechanical retention in the original framework was thought to be adequate, but additional retention with chemical bonding was thought to be reasonable to improve the longevity of the denture base/framework connection. It would also serve to opaque the metal framework. SiliClean and SiliLink were the materials used in the Silicoater MD oven (Heraeus Kulzer, Armonk, NY) (Figure 11.59).



Figure 11.60. Laboratory anterior view of the wax prostheses in the articulator.



Figure 11.62. Left laboratory view of the wax prostheses in the articulator. The posterior occlusion was set for maximum intercuspation and left group function working occlusion.



Figure 11.61. Right laboratory view of the wax prostheses in the articulator. The posterior occlusion was set for maximum intercuspation and right group function working occlusion.



Figure 11.63. Anterior clinical view of the patient with the wax prostheses in place. The centric jaw relation record was verified. Everyone was pleased with the overall aesthetic result. The patient and her spouse agreed to proceed with the processing phase of the treatment.

The mandibular denture teeth were set consistent with the positions of the denture teeth in the wax maxillary denture (Figures 11.60–11.62).

The patient, her spouse, and the author evaluated the aesthetics, lip support, occlusal vertical dimension, and rest vertical dimension of the wax prostheses at the wax try-in appointment. The author evaluated the accuracy of the jaw relation record per the above parameters. The dentures were deemed ready for processing only after all of the above had been completed (Figures 11.63 and 11.64).

PROCESSING

The prostheses were waxed to the appropriate contours. The maxillary denture was sealed to the cast, and the wax denture base of the mandibular fixed/detachable prosthesis was sealed into the finish lines (Figures 11.65 and 11.66). The prostheses were flaked in conventional fashion with vacuum-mixed dental stone, and the stone was allowed to set.

The molds were heated in boiling water, and the wax was eliminated after the flasks were separated. After the flasks had cooled, tinfoil substitute was applied to all of the stone surfaces so that they could be handled comfortably.



Figure 11.64. Clinical profile images with the wax prostheses in place (vertical dimension of rest position, left; smiling, right). The wax prostheses satisfied the patient and clinical aesthetic requirements.



Figure 11.65. Laboratory anterior image of both prostheses after the definitive waxing was completed; the prostheses were sealed to the maxillary cast and mandibular framework.

Heat-polymerized acrylic resin (Lucitone® 199, Dentsply International) was mixed according to the manufacturer's instructions, and the prostheses were processed overnight. The next morning, the flasks were allowed to cool to room temperature, and the prostheses were deflasked.

The prostheses were remounted in the articulator, and the occlusion was adjusted to compensate for any errors associated with processing. The prostheses were finished and polished in conventional fashion with acrylic resin burs, wheels, pumice, and polishing agents (Figures 11.67–11.70). It should be noted that polishing protectors (PPSA3,



Figure 11.66. Lingual laboratory view of the wax dentures in the articulator. There was light occlusal contact between the maxillary and mandibular anterior teeth. In order to facilitate optimal dimensions and contours for the screw access openings where possible, the waxing screws were left in their original lengths.



Figure 11.67. Laboratory occlusal view of the finished mandibular fixed/detachable prosthesis. The silicoating successfully blocked out any metal showthrough of the metal framework through the acrylic resin denture base.



Figure 11.68. Right laboratory occlusal view of the finished mandibular fixed/detachable prosthesis.



Figure 11.69. Left laboratory occlusal view of the finished mandibular fixed/detachable prosthesis.



Figure 11.70. Intaglio laboratory view of the finished mandibular fixed/detachable prosthesis. The acrylic resin denture base was finished consistent with the buccal and lingual finish lines in the cast metal framework. The design and locations of the finish lines, in conjunction with the silicoating, allowed the dental laboratory technician to finish the acrylic resin/metal junctions in a manner that should minimize stain forming at the junction of the acrylic resin denture base and the framework.

Biomet 3i) were always in place during all of the finishing/polishing procedures for the mandibular fixed/detachable prosthesis (Figure 11.71).

INSERTION

The patient returned for the insertion appointment. The healing caps were removed from the four mandibular abutments. The abutment screws were retorqued to 20Ncm with a torque device. None of the screws were loose, and the patient reported no discomfort. The mandibular prosthesis went to place without incident (Figure 11.72).



Figure 11.71. Polishing protectors (PPSA3) should always be used during polishing procedures for implant-supported frameworks. Polishing protectors are available for abutments and implants. This will protect the machined interfaces between the frameworks and implant restorative components from being damaged during the finishing process.



Figure 11.72. Clinical anterior view with the mandibular fixed/detachable prosthesis in place on the standard abutments. The denture processing procedures did not alter the fit between the framework and the abutments.

Retaining screws (GSH30, Biomet 3i) were placed into the screw access openings and torqued to 10Ncm with a torque driver. The screw heads inside the screw access openings were initially blocked out with cotton pellets (Figure 11.73). The access openings were restored with tooth-colored, light-cured composite resin (Figure 11.74).

The maxillary complete denture went to place with minimal clinical adjustments. The occlusion was evaluated in centric, right, left, and protrusive positions (Figures 11.75–11.77). The patient was extremely pleased with the results (Figures 11.78 and 11.79).



Figure 11.73. Clinical image of cotton placed into the left distal screw access opening. The cotton protects the head of the retaining screw (inset) from any damage that may occur if and when the retaining screw needs to be removed.



Figure 11.75. Clinical anterior view of the patient in centric occlusion, with both prostheses in place. The occlusion did not have to be adjusted at this clinical visit.



Figure 11.74. Clinical occlusal image of the mandibular fixed/detachable prosthesis in place after restoration of the screw access openings.



Figure 11.76. Right clinical view of the patient in centric occlusion at the time the prostheses were inserted.



Figure 11.77. Left clinical view of the patient in centric occlusion at the time the prostheses were inserted.



Figure 11.78. Clinical view of the patient smiling immediately post placement of the prostheses. By virtue of this treatment protocol, all of her chief complaints were taken care of with minimal inconvenience, as the process was completed in 4 days.

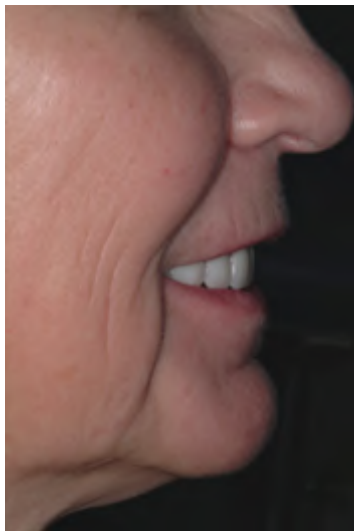


Figure 11.79. Clinical profile view of the patient smiling immediately post placement of the prostheses. By virtue of this treatment protocol, all of her chief complaints were taken care of with minimal inconvenience.

The following clinicians and dental laboratory technicians were responsible for the treatments illustrated in this chapter:

Prosthodontist: Carl Drago DDS, MS; LaCrosse, WI

Dental Laboratory Technician: Andrew Gingrasso, Onalaska, WI

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Index

- Abutment(s), 4–6
 cast, 61
 custom, 181–83, 183f, 184f
 Columbus Bridge Protocol
 impression of, 44–46, 44f, 45f, 46f, 46t
 placement of, 42–44, 43f, 44f
 crown-retained, 4–6, 6f
 CT-guided surgery and selection/placement of
 edentulous mandible, 153–54, 153f, 154f, 158–60, 160f, 161f
 edentulous maxillae, 270–73, 272f, 273f, 274f, 278–80, 279f, 280f
 custom cast, 181–82, 183f, 184f
 implant restoration platforms and, 183
 definitive, 86–87, 88f
 design, 80–81, 80f
 fixed collar height titanium, 165–79
 healing, 73–74, 74f, 86, 88f, 165, 167f
 CAD/CAM, 73–74, 74f, 86, 88f, 193, 194f
 CAD/CAM abutments with implant-retained crowns and, 193, 194f
 mandibular hybrid screw-retained prosthesis, 100, 100f
 implant connection to, 6
 implant crown restoration, 165
 implant interface with, 61, 62f, 217
 maxillary hybrid prosthesis with cast metal framework
 impression of, 44–46, 44f, 45f, 46f, 46t
 placement of, 42–44, 43f, 44f
 milling, 80–81, 81f
 occlusal loading, immediate
 impression of, 44–46, 44f, 45f, 46f, 46t
 placement of, 42–44, 43f, 44f
 overdenture, 11
 placement, 42–44, 43f, 44f, 165, 167f
 CT-guided surgery, edentulous mandible, 153–54, 153f, 154f, 158–60, 160f, 161f
 Procera, 217
 provisional prosthesis, selection of, 136–37, 137f
 screw, 89, 89f
 screw-retained, 4–6, 6f
 seating, 165, 167f
 selection, 6–7, 165, 169, 169f
 titanium, 165–79, 166f
 UCLA, 181–83, 183f
 use of custom cast, 183, 183f, 184f
- Abutment analogs
 implant restoration abutment, 173–74, 174f
 Provide Abutment, 165, 167f
- Abutment placement index, 89
- Acrylic resin dentures. *See also* Denture(s)
 free gingival margins in, replicating, 117–18, 118f
 injection molding protocols for, 117
 prosthodontics and processing of, 116–20
- Adesso® Split Mounting Plates, 77, 77f, 232
- Architech PSR®, 213, 214f, 215f
- Articulator mounting, 48–49, 48f, 49f, 49t
 Adesso® Split Mounting Plates, 77, 77f
 CAD/CAM abutment, 77, 77f
 with implant-retained crown, 197, 197f, 198f, 232–33, 233f
- Columbus Bridge Protocol, 33, 33f, 34f, 48–49, 48f, 49f, 49t
- mandibular hybrid screw-retained prosthesis, 102–4, 102f, 102t, 103f
- mandibular two-implant overdenture, 18, 18t, 19f, 19t
- maxillary hybrid prosthesis with cast metal framework, 33, 33f, 34f, 48–49, 48f, 49f, 49t
- occlusal loading, immediate, 33, 33f, 34f, 48–49, 48f, 49f, 49t
- replacement of denture teeth/base, 298, 299f, 302, 303f
- CAD. *See* Computer-aided design/computer-aided manufacturing
- CAD/CAM abutments, 61–91. *See also* Abutment(s)
 abutment design/milling for, 200–201, 200f, 201f, 202f, 240–43, 240f, 241f, 242f, 243f, 244f
 advantages of using, 61
 alumina, 217
 articulator mounting, 77, 77f
 assessment, 72
 casting custom, 183–84
 ceramic, 213–51
 clinical insertion, 86–90
 occlusion evaluation and, 89
 clinical patient presentation, 67, 71f, 72f
 definitive abutment, 89–90, 90f, 91f
 placement of, 86–87, 88f
 design, 80–81, 80f
 diagnosis, 67
 diagnostic casts/surgical guide, 72–73, 72f, 73f
 EHA, 64–68

- CAD/CAM abutments (*continued*)
 impressions, 74–76, 75f, 76f
 placement of, 74–76, 75f, 76f
 Encode, 213, 214f
 Encode® Complete Restorative System, 184–87, 184f–190f
 fabrication of porcelain-fused-to-metal crown and, 85–86, 86f, 87f
 healing, 193, 194f
 placement of, 73–74, 74f
 removal of, 86, 88f
 implant and attachment of, 87–89, 89f
 implant restoration and, 63, 90
 implant-retained crowns with, 181–210, 213–51
 abutment design/milling for, 200–201, 200f, 201f, 202f
 articulator mounting for, 197, 197f, 198f
 assessment of, 191–92
 clinical insertion of, 206–10, 208f, 209f, 210f
 clinical patient presentation, 187–91, 191f
 diagnosis for, 191
 diagnostic casts for, 192, 192f, 193f
 EHA placement/impressions for, 194–96, 195f, 196f
 Encode complete work order, 198, 199f
 healing abutment placement for, 193, 194f
 implant surgery, 192–93, 193f
 master cast for, 196–97, 197f
 porcelain-fused-to-metal crown fabrication and, 202–6, 205f, 206f, 207f, 208f
 robot analog placement for, 201–2, 202f, 203f, 204f, 236–40, 237f, 238f, 239f
 scanning for, 198–200, 200f
 surgical guide for, 192, 192f, 193f
 implant surgery, 73, 73f
 master cast, 76, 76f
 milling, 80–81, 81f
 scanning, 79–80, 79f
 titanium, 184
 use of, 213
 zirconia, 216
 Encode® Complete Restorative System and, 227, 227f
- CAD/CAM frameworks
 denture setup on, 114, 114f, 115f
 design/construction of, 104–14
 electroformed bar sleeves and, 108–9, 110f, 110t
 fit, 105, 107f
 mandibular hybrid screw-retained prosthesis, 104–14
 protocol, 105
 StructSURE Precision Milled bar and, 105–8, 106f, 107f, 108f, 108t, 109f
 tertiary casting and, 109–11, 110f, 111t
- CAM. *See* Computer-aided design/computer-aided manufacturing
- Casting. *See also* Tertiary casting
 CAD/CAM abutments, 183–84
 CAD/CAM protocol, 220–23, 220f, 222f
 maxillary overdenture, secondary, 93–123
 procedures, 216–17
 rotational misfit and, 216–17
- CBCT. *See* Cone beam CT
- Cement-retained crown, implant restoration, 89–90
- Centric relation (CR) record, 31–33, 32f, 33f
 impression materials, 33
 wax, 33
- Ceramic systems, 213
- CNC-milled titanium frameworks. *See* Computer numeric control-milled titanium frameworks
- Columbus Bridge Protocol, 27–57
 abutments
 impression of, 44–46, 44f, 45f, 46f, 46t
 placement of, 42–44, 43f, 44f
 articulator mounting, 33, 33f, 34f, 48–49, 48f, 49f, 49t
 assessment, 30–31, 30f, 30t
 clinical patient presentation, 28–30, 28f, 29f
 clinical visit, one-week post-insertion, 56–57, 57f
 diagnosis, 30
 diagnostics, 31–33, 31f, 32f, 33f
 implant placement, 40–42, 40f, 41f, 42f, 43f
 insertion, 54–56, 54f, 55f, 56f
 jaw relation records, 46–47, 46f, 47f
 master cast, 47–48, 47f, 48f
 screw-retained implant prosthesis, fabrication of, 49–53, 50f, 51f
 surgery, 40–42, 40f, 41f, 42f, 43f
 surgical guide, 33–39, 34f, 35f, 36f, 37f, 38f, 39f
 survival rate, 27–28
- Computed tomography (CT), 130–31, 255
 Dentascans, 131
 diagnostic capabilities of, 130–31, 255
 efficacy of, 130, 131f
 interactive, 256
 intraoral, scan, 147–50, 148f, 149f, 150f
 intraoral scan, 264–65, 265f, 266f, 267f
 scanning appliance, fabrication of, 146–47, 147f, 148f, 262–64, 263f, 264f
 treatment planning, accuracy in, 256–57
- Computed tomography (CT)-guided surgery
 edentulous mandible, 127–62
 abutment placement for, 153–54, 153f, 154f, 158–60, 160f, 161f
 abutment selection for, 153–54, 153f, 154f
 assessment of, 142
 clinical patient presentation, 139–40, 139f, 140f, 141f

- CT scanning appliance for, fabrication of, 146–47, 147f, 148f
- diagnosis for, 141–42
- framework fabrication for, 154–55, 154f, 155f, 156t
- implant analogs for, 150–52, 151f, 152f, 153f
- intraoral CT scan for, 147–50, 148f, 149f, 150f
- master cast fabrication for, 150–52, 151f, 152f, 153f
- postoperative visit, 162
- provisional prosthesis for, 155–57, 156f, 157f, 157t, 158f
- provisional prosthesis for, fabrication of, 154–55, 154f, 155f, 156t
- provisional prosthesis for, insertion of, 161, 161f, 162f
- radiographs in, 141, 141f
- surgical implant placement for, 157–58, 158f, 159f, 160f
- treatment plan for, 142
- wax dentures for, clinical try-in of, 145–46, 146f
- wax dentures for, construction of, 142–45, 142f, 143f, 144f, 145f
- edentulous maxillae, 253–83
 - abutment placement, clinical and, 278–80, 279f, 280f
 - abutment selection/placement for, 270–73, 272f, 273f, 274f
 - assessment of, 259
 - clinical patient presentation and, 257–58, 257f, 258f
 - diagnosis for, 259
 - framework fabrication for, 273–76, 275f, 275t
 - implant placement, surgical and, 278, 278f, 279f
 - intraoral CT scan in, 264–65, 265f, 266f, 267f
 - master cast with implant analogs for, 265–70, 268f, 269f, 270f, 271f, 272f
 - postoperative visit, 283, 283f
 - preoperative planning and, 257
 - provisional prosthesis for, 276–77, 276f, 277f
 - provisional prosthesis for, insertion of, 280–83, 281f, 282f, 282t
 - radiographs for, 258, 259f
 - scanning appliance for, fabrication of, 262–64, 263f, 264f
 - tilted implants and, 254–55
 - treatment plan, 259
 - wax dentures for, 259–62, 260f, 261f, 262f, 263f
- implant analog mounts and, 133–34, 133t, 134f
- master cast fabrication for, 135–36, 136f, 150–52
- master tubes for, 133, 133f
- prosthetic laboratory kit for, 133–34, 133t, 134f
- provisional prosthesis in
 - abutment selection for, 136–37, 137f
 - fabrication of, 137–39, 138f, 139f
 - master cast fabrication for, 135–36, 136f
 - surgical guides, 132, 132f
 - surgical kit components in, 134–35, 135f
- Computer-aided design/computer-aided manufacturing (CAD/CAM), 61
- dental, technology, 213
- Encode® Complete Restorative System, 219–23, 219f, 221f
- protocols, 213, 219–23, 219f
 - casting, 220–23, 220f, 222f
 - EHA and, 219–20, 220f
 - follow-up studies on, 218
- titanium frameworks, 218–19
- use, 213
- Computer numeric control (CNC)-milled titanium frameworks, 218
- Cone beam CT (CBCT), 255–56. *See also* Computed tomography
- Crown-retained abutment, 4–6, 6f
- Crowns. *See also* Implant-retained crown with CAD/CAM abutments
 - cement-retained, implant restoration, 89–90
 - implant, restorations, 89–90, 165
 - porcelain, 243–47, 245f, 246f, 247f
 - porcelain-fused-to-metal, 85–86, 86f, 87f, 202–10, 205f–210f
 - fabrication of, 85–86, 86f, 87f
- CR record. *See* Centric relation record
- CSR. *See* Cumulative survival rate
- CT. *See* Computed tomography (CT)
- CT-guided surgery. *See* Computed tomography-guided surgery
- Cumulative survival rate (CSR)
 - implant, 27–28
 - occlusal loading, immediate and, 253
 - maxillary implant, 93
 - osseointegration, 93
- Dentascans, 131
- Denture(s)
 - articulator mounting and, 298, 299f
 - CAD/CAM framework and setup of, 114, 114f, 115f
 - edentulous mandible, 287
 - mandibular complete, 11
 - maxillary complete, 287–88, 288f
 - maxillary impression for, 293–94, 293f, 294f
 - overdenture abutments, 11
 - overdenture attachments, 11
 - replacement of, 287–310
 - appointment sequence for, 291–92
 - articulator mounting and, 302, 303f
 - assessment for, 291
 - clinical jaw relation records and, 297–98, 298f

- Denture(s) (*continued*)
- clinical patient presentation for, 289–90, 290f, 291f
 - diagnosis, 290
 - diagnostic casts for, 292, 292f, 293f
 - insertion and, 308–10, 308f, 309f, 310f
 - mandibular master cast for, 301–2, 301f, 302f, 303f
 - mandibular wax denture and, 302–4, 303f, 304f, 305f
 - maxillary impressions for, 293–94, 293f, 294f
 - maxillary master cast for, 294, 295f
 - maxillary record base/wax occlusion rim and, 294–97, 295f, 296f, 297f
 - maxillary wax dentures for, 298–300, 300f, 301f
 - processing and, 306–8, 307f, 308f
 - silicoating and, 304–6, 305f, 306f
- Denture base, replacement of, 287–310
- appointment sequence for, 291–92
 - articulator mounting and, 298, 299f, 302, 303f
 - assessment for, 291
 - clinical jaw relation records and, 297–98, 298f
 - clinical patient presentation for, 289–90, 290f, 291f
 - diagnosis, 290
 - diagnostic casts for, 292, 292f, 293f
 - insertion and, 308–10, 308f, 309f, 310f
 - mandibular master cast for, 301–2, 301f, 302f, 303f
 - mandibular wax denture and, 302–4, 303f, 304f, 305f
 - maxillary impressions for, 293–94, 293f, 294f
 - maxillary master cast for, 294, 295f
 - maxillary record base/wax occlusion rim and, 294–97, 295f, 296f, 297f
 - maxillary wax dentures for, 298–300, 300f, 301f
 - processing and, 306–8, 307f, 308f
 - silicoating and, 304–6, 305f, 306f
- Diagnostic casts
- CAD/CAM abutments, 72–73, 72f, 73f
 - with implant-retained crowns, 192, 192f, 193f
 - implant-retained crown with CAD/CAM abutment, 227–28, 227f, 228f
 - mandibular hybrid screw-retained prosthesis, 96, 97f
 - mandibular two-implant overdenture, 14–15
 - robot analog placement, 72–73, 72f, 73f
- Edentulous mandible
- CT-guided surgery in, 127–62
 - dentures, 287
 - occlusal loading, immediate, 253
- Edentulous maxillae, 93, 94f
- CT-guided surgery in, 253–83
 - abutment placement, clinical and, 278–80, 279f, 280f
 - abutment selection/placement for, 270–73, 272f, 273f, 274f
 - assessment of, 259
 - clinical patient presentation and, 257–58, 257f, 258f
 - diagnosis for, 259
 - framework fabrication for, 273–76, 275f, 275t
 - implant placement, surgical and, 278, 278f, 279f
 - intraoral CT scan in, 264–65, 265f, 266f, 267f
 - master cast with implant analogs for, 265–70, 268f, 269f, 270f, 271f, 272f
 - postoperative visit, 283, 283f
 - preoperative planning and, 257
 - provisional prosthesis for, 276–77, 276f, 277f
 - provisional prosthesis for, insertion of, 280–83, 281f, 282f, 282t
 - radiographs for, 258, 259f
 - scanning appliance for, fabrication of, 262–64, 263f, 264f
 - tilted implants and, 254–55
 - treatment plan, 259
 - wax dentures for, 259–62, 260f, 261f, 262f, 263f
- CT treatment planning and, accuracy in, 256–57
- Edentulous patients
- aesthetics, 27
 - loss of natural teeth in, 27, 253
- EHA. *See* Encode® Healing Abutments
- Electroformed bar sleeves, 108–9, 110f, 110t
- Electroforming, 108–9
- Emergence Profile (EP) Healing Abutment System, 227, 227f
- Encode Abutment
- CAD/CAM, 213, 214f
 - cast mounting for, 185–87, 186f, 187f, 188f
 - clinical insertion, 206–10, 208f, 209f, 210f
 - Robocast™, 85
 - work order, 198, 199f
- Encode® Complete Restorative System, 64–67, 184–87
- CAD/CAM abutments, 184–87, 184f–190f
 - zirconia, 227, 227f
 - CAD/CAM protocol, 219–23, 219f, 221f
 - casts, 66–67, 66f
 - mounting, 66, 66f, 185–87, 186f, 187f, 188f
 - EHA, 64, 64f
 - implant-level impressions and, 65, 184–85
 - verification process, 79–80, 80f
 - work order, 66, 68f, 77–79, 78f
 - implant-retained crown with CAD/CAM abutments, 233–34, 234f
- Encode® Healing Abutments (EHA), 64, 64f, 69f, 70f.
- See also* Abutments
- CAD/CAM protocol and, 219–20, 220f

- casts, 66–67, 187
- design, 68, 184, 184f, 185f, 200–201, 201f
- height of, 75
- implant placement, 64–65
- impressions, 65, 65f, 74–76, 75f, 76f, 185, 185f
 - CAD/CAM abutments with implant-retained crowns and, 194–96, 195f, 196f
- master cast, 76, 76f
- milling, 200–201, 202f
- pieces, 75
- placement, 74–76, 75f, 76f
 - CAD/CAM abutments with implant-retained crowns and, 194–96, 195f, 196f, 228–32, 229f, 230f, 231f
 - scanning, 79–80, 80f
- Encode® Zirconia Designer Abutments, 217. *See also* Zirconia ceramics
- design/milling, 240–43, 240f, 241f, 242f, 243f, 244f
- Endosseous osseointegrated dental implants, 3
- EP Healing Abutment System. *See* Emergence Profile Healing Abutment System

- Fixed dental restorations, impression material for, 61–63
- Fixed/detachable prosthesis, mandibular
 - placement, 288, 288f, 289f
 - replacement of denture teeth/base for, 287–310
 - appointment sequence for, 291–92
 - articulator mounting and, 298, 299f, 302, 303f
 - assessment of, 291
 - clinical jaw relation records and, 297–98, 298f
 - clinical patient presentation of, 289–90, 290f, 291f
 - diagnosis of, 290
 - diagnostic casts for, 292, 292f, 293f
 - insertion and, 308–10, 308f, 309f, 310f
 - mandibular master cast for, 301–2, 301f, 302f, 303f
 - mandibular wax denture and, 302–4, 303f, 304f, 305f
 - maxillary impressions and, 293–94, 293f, 294f
 - maxillary master cast and, 294, 295f
 - maxillary record base/wax occlusion rim and, 294–97, 295f, 296f, 297f
 - maxillary wax dentures and, 298–300, 300f, 301f
 - processing and, 306–8, 307f, 308f
 - silicoating and, 304–6, 305f, 306f
- Fixed partial dentures (FPDs), 108
 - all-ceramic, 213
 - porcelain-fused-to-metal, 165–79
 - zirconia cores for, 215–16
- FPDs. *See* Fixed partial dentures
- Free gingival margins, replicating, 117–18, 118f

- Gold substructures, 108–9

- Hader bar-and-clip, 11
- Hybrid screw-retained prosthesis, 51–53, 52f, 53f, 54f
 - mandibular, 93–123
 - articulator mounting, 102–4, 102f, 102t, 103f
 - assessment, 95–96, 95f, 96f
 - CAD/CAM frameworks, 104–14
 - clinical patient presentation, 93–94, 94f, 95f
 - clinical try-in appointment for, 114–16, 115f, 116f, 117f
 - diagnoses, 95
 - diagnostic casts, 96, 97f
 - implant-level impressions, 98
 - implant surgery, 96–97, 97f
 - insertion, 121–23, 122f, 123f
 - jaw relation records, 100–101
 - master cast, 98–99, 100f, 100t
 - polishing, 118–19, 120f, 121f, 122f
 - processing of, 116–20, 118f, 119f, 119t
 - processing of, error in, 118, 120f
 - record bases, 100–101, 101f
 - surgical guide, 96, 97f
 - verification index, 102–4, 103f, 104f
 - wax dentures, 102–4, 103f, 104f

- ICT. *See* Interactive CT
- Imaging. *See also* Computed tomography
 - CT, 130–31
 - diagnostics, 127–30
 - postprosthetic implant, 129, 129f
 - preprosthetic implant, 127, 128f, 129f
 - panoramic radiography, 129, 129f
 - surgical/interventional implant, 127
- Implant analogs
 - CT-guided surgery and
 - edentulous mandible, 150–52, 151f, 152f, 153f
 - edentulous maxillae, 265–70, 268f, 269f, 270f, 271f, 272f
 - mounts, 133–34, 133t, 134f
 - CT-guided surgery and, edentulous mandible, 151, 151f
- Implant crown restorations, 165
- Implant dentistry
 - abutment/implant connection in, 6
 - abutments, 4–6
 - selection of, 6–7
 - bone density and, 27
 - implant choice/variation in, 6
 - implant CSR, 27–28
 - implant placement, 40–42, 40f, 41f, 42f, 43f
 - introduction to, 3–10
 - loading protocols, 3–4, 4f, 5f, 6f, 253
 - immediate, 27
 - occlusal, 27–57

- Implant dentistry (*continued*)
 - mandibular two-implant overdenture, 11–24
 - protheses, 3, 4f
 - surgical guides, 7–9
 - computer generated, 9, 9f, 10f
 - conventional, 7, 7f, 8f
- Implant-level impressions, 63
 - Encode® Complete Restorative System and, 65, 184–85
 - mandibular hybrid screw-retained prosthesis, 98, 98f, 99f
- Implant placement
 - Columbus Bridge Protocol, 40–42, 40f, 41f, 42f, 43f
 - CT-guided surgery
 - edentulous mandible, 157–58, 158f, 159f, 160f
 - edentulous maxillae, 278, 278f, 279f
 - EHA, 40–42, 40f, 41f, 42f, 43f, 64–65
 - maxillary hybrid prosthesis with cast metal framework, 40–42, 40f, 41f, 42f, 43f
 - occlusal loading, immediate, 40–42, 40f, 41f, 42f, 43f
- Implant prosthesis, 3, 4f
 - abutment connection to, 6
 - abutment interface with, 61, 62f, 217
 - CAD/CAM abutment attachment to, 87–89, 89f
 - definitive, implant restoration abutment, 175–77, 176f, 177f, 178f
 - endosseous osseointegrated, 3
 - hybrid, screw-retained implant prosthesis and, 51–53, 52f, 53f, 54f
 - occlusal overloading and, 119–20
 - occlusion, 120
 - success, 104
- Implant restoration. *See also* Fixed dental restorations
 - CAD/CAM abutments and, 63, 90
 - cement-retained crown, 89–90
 - dental techniques for, 63–64
 - Encode® Complete Restorative System, 64–67
 - fit and, 61
 - implants and, 61, 62f
 - metal-free, 213
 - presurgical planning phase, 181, 182f
- Implant restoration abutments, 165–79. *See also* Abutment(s)
 - aesthetic evaluation of, 178–79
 - analogs, 173–74, 174f
 - assessment, 168–69
 - clinical patient presentation, 168, 168f
 - definitive prosthesis, 175–77, 176f, 177f, 178f
 - diagnosis, 168
 - diagnostics, 169, 169f, 170f
 - impression, 172–73, 173f, 173t
 - insertion, 178, 178f
 - master cast with abutment analogs for, 173–74, 174f
 - selection, 169, 169f
 - surgery, 169–72, 170f, 171f, 171t, 172f
- Implant restoration platforms, 183
- Implant-retained crown with CAD/CAM abutments, 181–210
 - abutment design/milling for, 200–201, 200f, 201f, 202f, 240–43, 240f, 241f, 242f, 243f, 244f
 - articulator mounting for, 197, 197f, 198f, 232–33, 233f
 - assessment of, 191–92, 225–27, 226f
 - clinical insertion of, 206–10, 208f, 209f, 210f, 247–51, 247f, 248f, 249f, 250f, 251f
 - clinical patient presentation for, 187–91, 191f, 223–24, 224f
 - CNC-milled titanium frameworks for, 218
 - diagnosis for, 191, 225
 - diagnostic casts for, 192, 192f, 193f, 227–28, 227f, 228f
 - EHA placement for, 194–96, 195f, 196f, 228–32, 230f, 231f, 232f
 - Encode complete work order, 198, 199f, 233–34, 234f
 - healing abutment placement for, 193, 194f
 - implant/abutment interface in, 217
 - implant surgery, 192–93, 193f, 228, 229f
 - impression, 195f, 196f, 194–96
 - master cast for, 196–97, 197f, 232, 232f, 233f
 - porcelain crown fabrication for, 243–47, 245f, 246f, 247f
 - porcelain-fused-to-metal crown fabrication and, 202–6, 205f, 206f, 207f, 208f
 - robot analog placement for, 201–2, 202f, 203f, 204f, 236–40, 237f, 238f, 239f
 - scanning for, 198–200, 200f, 235–36, 235f, 236f
 - single-unit, 213–51
 - surgical guide for, 192, 192f, 193f, 227–28, 227f, 228f
- Implant-retained prosthesis, 287–88
- Implant surgery
 - CAD/CAM abutments, 73, 73f
 - implant-retained crowns with, 192–93, 193f
 - Columbus Bridge Protocol, 40–42, 40f, 41f, 42f, 43f
 - implant-retained crown with CAD/CAM abutment, 228, 229f
 - mandibular hybrid screw-retained prosthesis, 96–97, 97f
 - maxillary hybrid prosthesis with cast metal framework, 40–42, 40f, 41f, 42f, 43f
 - robot analog placement, 73, 73f

- Impression procedures, 63
- Interactive computer software, 132, 132f
- Interactive CT (ICT), 131–32. *See also* Computed tomography (CT)
- Jaw relation records
 - Columbus Bridge Protocol, 46–47, 46f, 47f
 - mandibular hybrid screw-retained prosthesis, 100–101
 - maxillary hybrid prosthesis with cast metal framework, 46–47, 46f, 47f
 - occlusal loading, immediate, 46–47, 46f, 47f
- Laboratory analogs, Provide Abutments, 165, 167f
- Loading protocols
 - Columbus Bridge Protocol, 27–57
 - immediate, 27
 - nonocclusal, 3–4, 5f, 6f
 - occlusal, 3, 5f
 - immediate, 27–57
 - unloaded healing
 - single-stage, 3, 5f
 - traditional, two-stage, 3, 4f
- Locator attachments, 11
- Mandibular hybrid screw-retained prosthesis
 - articulator mounting, 102–4, 102f, 102t, 103f
 - assessment, 95–96, 95f, 96f
 - CAD/CAM frameworks, 104–14
 - clinical patient presentation, 93–94, 94f, 95f
 - diagnoses, 95
 - diagnostic casts, 96, 97f
 - healing abutments, 100, 100f
 - implant-level impressions, 98, 98f, 99f
 - implant surgery, 96–97, 97f
 - jaw relation records, 100–101
 - master cast, 98–99, 100f, 100t
 - record bases, 100–101, 101f
 - surgical guide, 96, 97f
 - VDR, 101, 101t
 - verification index, 102–4, 103f, 104f
 - wax dentures, 102–4, 103f, 104f
- Mandibular two-implant overdenture, 11–24. *See also* Overdenture attachments
 - articulator mounting, 18, 18t, 19f
 - assessment, 12–14
 - clinical patient presentation, 12, 13f, 14f
 - custom impression trays, 15, 15f, 15t, 16f
 - definitive intraoral impression, 16, 16f
 - diagnosis, 12
 - diagnostic casts, 14–15, 14f, 15f, 15t
 - insertion, 24, 24f
 - master cast, 16–17, 17f
 - processing, 21–23, 22f, 22t, 23f, 23t
 - record bases, 17, 18f, 18t
 - wax dentures and, 18–21, 20f, 21f
- Mandibular wax denture, 302–4, 303f, 304f, 305f
- Master casts, 47–48, 47f, 48f
 - CAD/CAM abutments with implant-retained crown, 196–97, 197f
 - CT-guided surgery and fabrication of
 - edentulous mandible, 150–52, 151f, 152f, 153f
 - edentulous maxillae, 265–70, 268f, 269f, 270f, 271f, 272f
 - fabrication of, for immediate, fixed provisional prosthesis, 135–36, 136f
 - implant restoration abutment, 173–74, 174f
 - implant-retained crown with CAD/CAM abutments, 232, 232f, 233f
 - mandibular, replacement of denture teeth/base and, 301–2, 301f, 302f, 303f
 - mandibular hybrid screw-retained prosthesis, 98–99, 100f, 100t
 - maxillary, 294, 295f
- Maxillary complete dentures, 287–89, 288f
 - maxillary impression for, 293–94, 293f, 294f
- Maxillary dentures, wax, 298–300, 300f
- Maxillary hybrid prosthesis with cast metal framework, 27–57
 - abutments
 - impression of, 44–46, 44f, 45f, 46f, 46t
 - placement of, 42–44, 43f, 44f
 - articulator mounting, 33, 33f, 34f, 48–49, 48f, 49f, 49t
 - assessment, 30–31, 30f, 30t
 - clinical patient presentation, 28–30, 28f, 29f
 - clinical visit, one-week post-insertion, 56–57, 57f
 - diagnosis, 30
 - diagnostics, 31–33, 31f, 32f, 33f
 - implant placement, 40–42, 40f, 41f, 42f, 43f
 - insertion, 54–56, 54f, 55f, 56f
 - jaw relation records, 46–47, 46f, 47f
 - master cast, 47–48, 47f, 48f
 - screw-retained implant prosthesis, fabrication of, 49–53, 50f, 51f
 - surgery, 40–42, 40f, 41f, 42f, 43f
 - surgical guide, 33–39, 34f, 35f, 36f, 37f, 38f, 39f
- Maxillary implant overdenture treatment, 95–96, 96t
- Maxillary implant-retained primary bar, 93–123
- Maxillary implants
 - CSRs for, 93, 94f
 - splinting together, 93
- Maxillary overdenture, secondary casting, 93–123

- Maxillary sinus grafting protocols, 30, 30f, 31f
- Metal framework, resin matrix attachment to, 113
- Navigator Laboratory Kit, 133–34, 133t, 134f
- Occlusal loading, 3–4, 5f, 6f
- Occlusal loading, immediate, 127, 128f
 - abutment impression, 44–46, 44f, 45f, 46f, 46t
 - abutment placement, 42–44, 43f, 44f
 - articulator mounting, 33, 33f, 34f, 48–49, 48f, 49f, 49t
 - assessment, 30–31, 30f, 30t
 - clinical patient presentation, 28–30, 28f, 29f
 - clinical visit, one-week post-insertion, 56–57, 57f
 - diagnosis, 30
 - diagnostics, 31–33, 31f, 32f, 33f
 - edentulous mandible, 253
 - edentulous maxillae, 253–83
 - implant placement, 40–42, 40f, 41f, 42f, 43f
 - implant survival after, 253
 - insertion for, 54–56, 54f, 55f, 56f
 - jaw relation records, 46–47, 46f, 47f
 - master cast, 47–48, 47f, 48f
 - maxillary hybrid prosthesis with cast metal framework, 27–57
 - screw-retained implant prosthesis, fabrication of, 49–53, 50f, 51f
 - surgery, 40–42, 40f, 41f, 42f, 43f
 - surgical guide, 33–39, 34f, 35f, 36f, 37f, 38f, 39f
- Occlusal overloading, dental implants and, 119–20
- Occlusion
 - implant, 120
 - wax, rim, 294–97, 295f, 296f, 297f
- Osseointegration, 27, 287–88
 - CSR, 93
 - occlusal forces and, 119–20
- Overdenture attachments, 11
 - bar, 11
 - complications, 11
 - fractures, 11, 12f
 - Hader bar-and-clip, 11
 - Locator, 11
 - maxillary implant, 95–96, 96t
 - new technology, 11, 12f, 13f
 - nonsplinted stud-type, 11
 - selection, 11
 - splintered, 11
- Panoramic radiography, 129–30, 129f, 130f
- Porcelain crowns, implant-retained crown with CAD/CAM abutments and fabrication of, 243–47, 245f, 246f, 247f
- Porcelain-fused-to-metal crown
 - clinical insertion, 206–10, 208f, 209f, 210f
 - design, 86
 - fabrication of, 85–86, 86f, 87f
 - CAD/CAM abutments with implant-retained crown and, 202–6, 205f, 206f, 207f, 208f
- Porcelain-fused-to-metal FPD, 165–79
- Power Cast Investment, 175, 175t
- Procera abutments, 217
- Prosthodontics, acrylic resin processing in, 116–20
- Provide Abutments, 165–68, 166f. *See also* Abutment(s)
 - laboratory analogs, 165, 167f
 - placement, 165, 167f
 - Placement Kit, 168, 168f
 - Restorative Kit, 168, 168f
 - temporary cylinders, 165, 168f
 - waxing sleeves, 165, 167f, 174–75, 174f, 175f, 175t, 176f
- Provisional prosthesis
 - CT-guided surgery
 - edentulous mandible, 154–57, 154f, 155f, 156f, 156t, 157f, 157t, 158f
 - edentulous maxillae, 276–77, 276f, 277f
 - CT-guided surgery, insertion of
 - edentulous mandible, 161, 161f, 162f
 - edentulous maxillae, 280–83, 281f, 282f, 282t
- Provisional prosthesis, fixed
 - master cast fabrication for, 135–36, 136f
 - screw-retained
 - abutment selection for, 136–37, 137f
 - fabrication of, 137–39, 138f, 139f
- QuickBridge PEEK caps, 279–80, 280f
- Radiography
 - body section, 129–30
 - CT-guided surgery, edentulous maxillae, 258, 259f
 - panoramic, 129–30, 129f, 130f
- Record bases
 - mandibular hybrid screw-retained prosthesis, 100–101, 101f
 - mandibular two-implant overdenture, 17, 18f, 18t
 - maxillary, 294–97, 295f, 296f, 297f
- Reflex® porcelain, 176–77, 177t, 178f
- Resin matrix, metal framework and attachment of, 113
- Robocast™, 66–67, 81–85, 82f, 83f, 84f, 85f
 - CAD/CAM abutments with implant-retained crown, 201–2, 202f, 203f, 204f, 236–40, 237f, 238f, 239f

- Encode Abutment, 85
- fabrication, 67, 69f, 70f, 187, 189f, 190f
- process of, accuracy, 81
- Robot analog placement
 - into cast, 81–85, 82f, 83f, 84f, 85f
 - assessment, 72
- CAD/CAM abutments and, 61–91
- CAD/CAM abutments with implant-retained crown, 201–2, 202f, 203f, 204f, 236–40, 237f, 238f, 239f
- clinical insertion, 86–90
- clinical patient presentation, 67, 71f, 72f
- diagnosis, 67
- diagnostic casts/surgical guide, 72–73, 72f, 73f
- fabrication of porcelain-fused-to-metal crown and, 85–86, 86f, 87f
- implant surgery, 73, 73f
- Robocast™, 66–67, 81–85, 82f, 83f, 84f, 85f
- scanning, 79–80, 79f
- Rotational misfit, 216–17

- Screw-retained abutments, 4–6, 6f
- Screw-retained implant prosthesis. *See also* Implant prosthesis
 - fabrication of, 49–53, 50f
 - construction of cast metal framework for, 49–51, 51f
 - construction of hybrid prosthesis in, 51–53, 52f, 53f, 54f
 - hybrid, 51–53, 52f, 53f, 54f
 - mandibular, 93–123
 - provisional
 - abutment selection for, 136–37, 137f
 - fabrication of, 137–39, 138f, 139f
- Silicoating, 113
 - replacement of denture teeth/base and, 304–6, 305f, 306f
- SimPlant software, 132, 132f
- StructSURE Precision Milled bar, CAM, 104–14
 - accuracy, 105
 - anterior attachments, 107–8, 108f
 - fabrication, 105, 106f
 - mandibular, 93, 111–13, 111f
 - designs for, 111–12, 112f
 - framework for, 113, 113f
 - software download for, 112–13
 - work order for, 111
 - maxillary copy, 105–8, 107f
 - posterior attachments, 108
 - protocol, 105
 - resin pattern, 107, 108f, 109f
 - silicoating, 113
 - SwissLoc attachments, 108, 108t
- Surgical guides
 - CAD/CAM abutment, 72–73, 72f, 73f
 - with implant-retained crowns, 192, 192f, 193f
 - Columbus Bridge Protocol, 33–39, 34f, 35f, 36f, 37f, 38f, 39f
 - CT-guided surgery, 132, 132f
 - implant dentistry, conventional, 7, 7f, 8f
 - implant-retained crown with CAD/CAM abutment, 227–28, 227f, 228f
 - mandibular hybrid screw-retained prosthesis, 96, 97f
 - maxillary hybrid prosthesis with cast metal framework, 33–39, 34f, 35f, 36f, 37f, 38f, 39f
 - occlusal loading, immediate, 33–39, 34f, 35f, 36f, 37f, 38f, 39f
 - robot analog placement, 72–73, 72f, 73f
 - SwissLoc attachments, 108, 108t
- Tertiary casting, 109–11, 110f, 111t
- 3Shape Scanner, 79–80, 79f
- Tilted implants, 127, 128f
 - edentulous maxillae CT-guided surgery and, 254–55
- Titanium abutments, 165–79, 166f
 - CAD/CAM, 184
- Titanium frameworks, CAD/CAM, 218–19. *See also* Computer numeric control-milled titanium frameworks
- Tomography, 129–30, 130f

- UCLA abutments, 181–83, 183f
 - use of custom cast, 183, 183f, 184f
- Unloaded healing
 - single-stage, 3, 5f
 - traditional, two-stage, 3, 4f

- VDR. *See* Vertical dimension of rest
- Verification index, mandibular hybrid screw-retained prosthesis, 102–4, 103f, 104f
- Vertical dimension of rest (VDR), 101, 102f
 - mandibular hybrid screw-retained prosthesis, 101, 101t
 - modeling compound, 101, 101t

- Wax dentures. *See also* Denture(s)
 - edentulous mandible CT-guided surgery
 - clinical try-in of, 145–46, 146f
 - construction of, 142–45, 142f, 143f, 144f, 145f
 - edentulous maxillae, CT-guided surgery and, 259–62, 260f, 261f, 262f, 263f
 - mandibular, 302–4, 303f, 304f, 305f

- Wax dentures (*continued*)
 mandibular hybrid screw-retained prosthesis,
 102–4, 102f, 103f, 104f
 mandibular two-implant overdenture and, 18–21,
 20f, 21f
 maxillary, 298–300, 300f, 301f
- Waxing sleeves
 implant restoration abutment, 174–75, 174f, 175f,
 175t, 176f
- Provide Abutments, 165, 167f, 174–75, 174f, 175f,
 175t, 176f
- Wax occlusion rim, maxillary, 294–97, 295f, 296f,
 297f
- Wiron® 99 Alloy, 109–11, 111t
- Zirconia ceramics, 213–14
 CAD/CAM abutments, 216
 FPDs and, 215–16